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Root and Top Growth Response of Five Woody Ornamental Species to in Field Fabric Containers, Bed Height, Trickle Irrigation, Fertilizer Source and Fertilizer Rate in Louisiana.

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Root and Top Growth Response of Five Woody Ornamental Species to In-field Fabric Containers, Bed Height, Trickle Irrigation, Fertilizer Source and Fertilizer Rate in Louisiana.

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ABSTRACT

Fabric field container studies were initiated in April, 1985, and continued for two years. The following four treatment combinations were evaluated; 1) production methods and trickle irrigation; 2) fertilizer sources and trickle irrigation; 3) fabric field container size, trickle irrigation, and fertilizer application methods; and 4) rate of slow-release fertilizer. Uniform 3.8 liter container-grown liners of *Acer rubrum* (red maple), *Betula nigra* (river birch), *Pinus Elliotti* (slash pine), *Quercus virginiana* (live oak), and *Taxodium distichum* (bald cypress) were transplanted in each of the studies, and *Liriodendron tulipifera* (tulip tree) was also included in study four. Production methods included balled and burlap (B&B) trees grown in flat and raised beds and 46-cm-diameter fabric field container trees grown in flat beds.

Plant production method did not influence first or second year plant height and trunk caliper of *Acer, Pinus, Quercus* and *Taxodium*, whereas, *Betula* plant height was reduced by the fabric container. Fabric containers resulted in 65-76% (*Acer*), 32-39% (*Betula*), 97-110% (*Pinus*), and 25- 80% (*Taxodium*) increase in root mass density compared with B&B treatments after 2 years. Root dry weights were 28% higher for irrigated trees compared with nonirrigated trees. Fabric container root balls of *Acer* and *Quercus* were sensitive to postharvest handling. The increased root mass density of *Taxodium* trees grown in fabric containers resulted in an increase in root growth potential compared with B&B trees.

Fertilizer sources had no effect on first and second year plant heights and trunk caliper of trees grown in 46-cm-diameter fabric containers. Species varied in response to trickle irrigation in study 3. *Betula, Quercus,* and *Taxodium* responded in a positive manner to trickle irrigation. Top growth and harvested root systems of *Acer* and *Pinus* were negatively affected by trickle irrigation.

N rates greater than 84 kg/ha/yr were not beneficial to top growth for *Betula, Liriodendron* and *Quercus* trees grown in 46-cm-diameter fabric containers. *Acer* and *Pinus* did not benefit from N rates higher than 168 kg/ha/yr, and *Taxodium* produced best growth at a N rate of 252 kg/ha/yr.

Introduction

Transplanting results in a drastic reduction of a tree's root system. It has been estimated that as little as 2% of the original root soil volume is moved with a typical nursery tree (131). Calculations of total root length remaining in the harvestable root ball range from 5.3% to 8.5% (38). Each species has a characteristic root:shoot ratio which remains constant in a stable environment and decreases progressively with plant age and size (64). Maintaining a proper balance between the root system and the crown is necessary for optimum growth (129). Minimizing the imbalance imposed by harvesting should allow the plant to re-establish its characteristic root:shoot ratio at a more rapid rate, resulting in maximum survival and rapid growth.

Restricting the roots with a fabric barrier is an attempt at increasing the amount of roots moved with transplanted trees. Initial studies suggested that the use of fabric root barriers had the potential to increase harvestable root mass, improve transplant establishment rate, and extend harvest season while decreasing the required root ball size and harvesting labor costs (95,126,135,136,137). None of these studies, however, has actually included replicated treatments of conventional B & B (balled and burlapped) plants for comparative purposes.

In Louisiana, most field nursery stock is grown on raised beds and balled and burlapped. Fabric field containers may offer some improvements in minimizing the root:shoot imbalance compared to conventional B & B nursery stock. For woody species commonly grown in Louisiana, it has not been determined if restricting the roots will result in dwarfing of plant material and if appreciable increases can be obtained in root mass and root growth potential. Interactions between the fabric field container and irrigation, fertility, and fabric field container size have not been studied. Therefore, a field study was initiated in 1985 to determine root and top growth responses of five woody ornamental species to fabric field containers, B & B treatments, trickle irrigation, fertilizer source and fertilizer rate. Information obtained from this study will be utilized in making recommendations to nursery field producers in Louisiana.

Review of Literature

A primary concern of research with nursery production is the maintenance of a proper balance between the root system and the crown of the plant and a distruption of this balance can result in transplant shock. One might assume that more roots in the root ball should result in increased survival and growth of transplanted trees. This assumption, however, does not take into account what component parts of the root system are increased and the internal controls of the plant on root growth. In order to examine the effects of nursery and transplanting practices on root system distribution and root regeneration, it is necessary to have an understanding of associated terminology and methods available for measurement of root systems.

Terminology and measurement of root systems

Root growth potential (RGP) is a measure of the capacity of planting stock rapidly to grow new roots (62). Other terms such as root growth capacity (15), root regeneration (128), root regeneration potential (25) and root-regenerating potential (72) are used interchangeably throughout the literature.

Ritchie (99) describes a standard method for measuring RGP in forest tree seedlings in the following manner: Tree seedlings are lifted and any new white tips are removed. The seedlings are potted and held in a test environment under ideal conditions for root growth as determined for the species in question. After 28 days they are excavated and new root production quantified. Whitcomb (136) similarly transplanted plants grown in

18 inch fabric field containers into 28-inch-diameter containers and evaluated the new root production after 30 days. When using these methods, root growth potential (RGP) can be expressed as the total number of new roots greater than 1 cm in length (69), as total length of new roots (67) and as weight or volume of new roots (4).

The soil-core method involves removing cylindrical core samples from the soil profile and washing the soil from the roots. Barnett (8) estimated root growth after transplanting plants in one-gallon containers by collecting core samples as a function of depth and distance from the plant crown 4, 7, 9, 11, 16, and 21 weeks after planting. Watson and Himelick (132) also used the soil-core sampling method to measure new root production on transplanted trees (44 inch root ball) one year after the date of transplanting. Many researchers report their results in terms of root mass density (119). In studying water uptake by a plant root system it is important to consider estimating root length density (8). The estimates are made on washed root samples, usually based on the line-intercept method of Newman (83).

The soil-core method of sampling roots is impractical in stony, gravelly, in low-coherence soils, or in soil containing roots greater that 2mm in diameter (119). Root distribution studies of older plant material usually require partial or entire excavation of the root system. This method can be time- consuming and roots less than 2mm in diameter are usually not recorded (38). Preston (93) estimated that one person needs 5 weeks to excavate, measure, and record the root system of a 15- year-old pine tree.

Excavation may give the only clear picture of a root system's symmetry with respect to soil depth and quadrants relative to north. Watson and

Himelick (131) partially excavated eighty-eight trees with a 44 inch mechanical tree spade. The wall of the cone-shaped hole was examined for roots of 1 cm in diameter or greater. The location, depth and size of severed roots were plotted on a map representing the outer surface of the root ball. Gilman (38) excavated 3 species of trees (six replicates each) and calculated the total root length within and outside a standard-size root ball.

Some researchers choose to divide the roots into 3 size classes: 1) fibrous - up to 1mm (.04 in) diameter, 2) secondary - greater than 1 mm (.04 in) but less than 1 cm (.4 in) in diameter, and 3) primary - 1 cm (.4 in) in diameter and larger (31,87,88,90). Roots are separated from the soil, washed, and dry weight determined. The root weights of the different root classes are usually determined for root balls that comply with American Association of Nurserymen specifications (2).

Other methods for studying root systems, such as trench-profile, Monolith, minirhizotrons, rhizotron, and ^{32}P or ^{15}N tracer are reviewed in Taylor (119) and Atkinson (5). These methods are used infrequently when studying the effects of nursery and transplanting practices on root distribution and root growth potential. Taylor (119) maintains that root growth and root system architecture studies are so tedious and time consuming that one should choose the easiest and simplest method that will provide the desired information.

Root distribution and its relationship to top growth

Stout (112), excavated and studied the root systems of nine native deciduous trees at a number of locations. The ratio between the area of the root system and the area of the crown ranged between 3.4:1 and 6.1:1

for 18 of the excavated trees. A mean root-crown ratio of 4.5:1 was obtained for these 18 trees.

Hopkins and Donahue (52) characterized the root systems of yellow birch, sugar maple, beech, balsam and spruce as related to soil depth. They found that 70-80% of the roots of all species studied were in the A horizon. The root distribution of fibrous and surface roots was highly correlated with organic matter. Yellow birch trees had the most exstensive root system in the B_3 horizon, whereas beech trees exhibited no root growth in the B_3 horizon. No correlation was made between tree height and root length.

Pan and Bassuk (85) in addressing the problem of "early-street-tree-mortality", investigated the root system of *Ailianthus altissima*, which naturally colonizes and thrives despite a hostile environment. They found *Ailianthus* roots were coarse, unbranched and wide spreading, whereas *Acer plantanoides* and *Liquidambar styraciflua* roots were fine, fibrous and confined to the area of the original planting hole. Lateral roots of *Ailianthus* were three to four times as long as that of the other two species.

Fare et al. (31) related that the poor transplant characteristics of 'Burfordii' holly may be due to a low percentage of fibrous and secondary roots in the root balls dug to American Associaton of Nurserymen specifications (2). 'Nellie R. Stevens' holly had about 3 times more fibrous and 2 times more secondary roots then 'Burfordii' holly and has a corresponding higher rate of transplant success. Struve and Moser (113) determined that pin oak was easier to transplant than scarlet oak because it had a greater amount of primary, secondary and fibrous roots.

Watson and Himelick (131) did some of the most definitive work on root distribution as it relates to nursery trees. They worked with eighty-eight trees of seven species that were harvested with a 44 inch mechanical tree spade. They constructed a model of a typical nursery-grown tree from these observations and other studies, and concluded that the root ball represents 2% of the original soil volume occupied by the tree's root system. Their results were also in agreement with other studies which consistently report that the highest densities of roots are in the upper soil horizons. It was also determined that five of the seven species developed their highest count of roots in the northern quadrant.

Gilman (38) excavated the root systems of *Gleditsia triacanthos*, *Populus* x *generosa*, and *Fraxinus pennsylvania* after three years and determined the root length remaining inside the harvestable root ball ranged from 5.3% to 8.5% of the total root length. All three species had greater root length outside the branch dripline than within. Thirty-five percent of poplar roots were located greater than 2 times the distance from the trunk to the branch dripline; however, only 16.8% and 7.8% locust and ash root length, respectively, were in this region. This work represents the first attempt to quantify the relationship between horizontal root distribution and branch spread. Gilman et al. (39) also determined that the root spread for young trees (*Gleditsia triacanthos*) three growing seasons after planting was predicted reliably from stem diameter or branch radius measurements. Roots extended as average of slightly less than three times the distance from the trunk to the dripline. There was no tendency toward increased growth in the northern quadrant as observed with other species (131). Also, these researchers did not observe any relationship between shape of the branch crown and root system, such as increased root growth on the side of the tree with increased shoot branching.

Internal control of root growth

The initiation of root growth is controlled by some stimulus originating in the shoots of the plant. Richardson's (96) early work with sugar maple demonstrated that physiologically dormant buds suppressed root growth and weakened the RGP response. The bud dormancy is developed in the fall and is released by chilling temperatures during the winter and spring months or by cold storage treatment. Other researchers have also shown that the RGP response is decreased unless the chilling requirements of the shoots has been satisfied (35,36,59,72). Luthrop and Mecklenburg (71) reported that root dormancy, as well as shoot dormancy, was inversely related to RGP in *Taxus* spp.

Sites of origin in conifers are different from those angiosperms previously discussed. Ritchie (99) found that bud removal had only a modest effect on RGP from November through December in Douglas Fir seedlings, while girdling and needle removal completely prevented intiation of new roots.

Root growth potential (RGP) in Ponderosa pine reaches a peak in the spring prior to bud-break and in the fall (111). The spring peak is due to both root initiation and elongation, whereas the fall peak is due exclusively to elongation of existing roots. Similar seasonal periodicity of root growth potential has been noted in several other woody species (59,71,72,73).

Hormonal factors orginating in the stem are likely responsible for the initiation of root growth. From tissue culture work it is well known that root and shoot initiation is tightly controlled by the auxin-cytokinin ratios (106). Tobacco cell-supension lines that lost their ability to regenerate roots have no detectable membrane-bound auxin-binding proteins (76). Ethylene has also been implicated in root growth and differentiation (94). Higher levels of auxin will result in an increased synthesis of ethylene (80). If ethylene synthesis is blocked, then high concentrations of IAA will no longer inhibit root growth but will stimulate it. This may explain why higher levels of auxin tend to stimulate intiation of new roots and lower concentrations stimulate elongation.

Farmer (34) found that auxins applied to roots of decapitated plants stimulated root regeneration while inhibiting shoot growth. Carlson (17) determined that endogenous IAA levels in red oak increased between root pruning and the appearance of new lateral roots. Auxin and cytokinin levels were also increased in the root xylem 24 hours after root pruning red oak (16). A number of studies have demonstrated the promotional effects of auxins on root initiation (41,59,72,74,75,77,92,97,104,109,114).

Gibberellin promoted shoot growth at the expense of root growth in *Quercus robus* (107). Simultaneous application of auxin restored root growth to normal levels. Cytokinin activity in the sap of *Quercus robus* reached a maximum 20 to 25 days before bud- break. Cytokinin activity in root extracts was lowered after a single flush of shoot growth. Reduced transport of gibberellins and cytokinins from roots of bean plants may be partly responsible for the retarded shoot growth observed in root-restricted plants (18). Sweet and Rook (115) root-pruned pine seedlings and found a reduction of ABA (50% lower than control) in roots was associated with an increase in root growth.

Extracts of root tip samples from spring-dug *Tilia cordata* cultivars had the greatest ability to promote root initiation on mung bean cuttings compared with other digging-planting times (141), yet root regeneration was greatest for fall-dug, fall-planted trees. Shoot growth is commencing in the spring and is probably depriving the root system of a constant supply of photosynthate. *Pistacia chinensis* 'Bunge' seedlings, after completion of shoot elongation (Fall), have a peak in RGP (72). Disbudding at spring bud-break or sucrose feeding via the stem substantially increases RGP at spring bud-break. In many deciduous trees, carbohydrate reserve levels normally decrease sharply during spring growth and reach a minimum in early summer (64,130). The onset of spring growth is believed responsible for the sharp drop in reserve carbohydrates. Carbohydrate levels are usually highest in the fall, and autumn foliage is important to the reserve carbohydrate status. Defoliation of apple trees four to six weeks before natural leaf-fall delayed the onset of root growth the following year (50). Removal of red oak leaves in autumn also reduced the RGP the following spring (70).

Richardson (98) demonstrated that 2-year-old *Acer saccharinum* trees were less dependent on current photosynthate production and more on reserves for root growth than first year seedlings. It required seven days of shading to inhibit root growth. Watson and Himelick (132) determined that nonstructural root carbohydrates in Norway maple were lowest during the spring growth period and RGP was also decreased. They also found that the roots of transplanted Norway maple trees accumulated higher carbohydrate levels than nontransplanted trees. They speculated that the root system of transplanted trees is so drastically reduced in relation to the crown, that photosynthates are produced faster than can be utilized. Carbohydrates have also been shown to accumulate at the base of severed or girdled stem cuttings, and were associated with increased root production (110).

No apparent correlation was found between RGP and reserve nonstructural carbohydrate levels in the foliage, stems, or roots in Douglas Fir seedlings stored over various lengths of time (99). These observations led Ritchie and Dunlap (99) to believe that while root activity requires carbohydrates, the level of food reserves does not alone control root growth. They summarized that once new root growth had been triggered and was proceeding in a favorable environment, its rate appeared to be influenced by an internal carbohydrate source-sink relationship. Prior to bud-break, roots are the major metabolic sink in the plant and are actively drawing upon currently assimilated (conifers) or stored (hardwoods) carbohydrate resources. Resumption of shoot elongation is accompanied by a rapid decline in root growth, suggesting a sink-strength reversal favoring the new shoot. After shoot elongation is completed, root activity may resume if environmental conditions permit.

Effect of cultural practices in the nursery on top growth and root growth potential (RGP)

container design and size

The first thing to consider before all else is the quality of plant material to be transplanted in the field for nursery production. Most nurseries grow their own liners for field planting and have control over the initial production period. Container plants have been shown to be superior to conventional bed-grown plants with initial growth prior to transplanting and continued growth in the field (48,135). The initial fertility of the container medium is also an important factor, and has a continued effect long after transplanting into the field. Plants grown with osmocote and micronutrients in the container medium were significantly larger after one growing season in the field compared with plants without amendments (48).

Container size is an important consideration in growing tree seedlings. A number of researchers have obtained superior plant growth with larger volume containers during the first year of liner production (4,47,117). Hanson (47) determined that the ratio of potting medium surface area to potting medium depth gave a positive correlation to seedling dry weight accumulations in northern red oak. Appleton (4) observed that the superior growth of 14 tree species (deciduous and coniferous) as a result of seeding into larger volume containers continued into the second season after transplanting.

Both air-root-pruning and vertical or stair-step ribs on the container wall have been developed to prevent root circling and eventual girdling. Some researchers have also observed an increased fibrous root mass and faster root regeneration after transplanting in the field using these containers (26,49,137,138). Newman and Follett (82), however, found no difference in primary or fibrous root dry weights of stair-stepped, standard round, or air-root pruned containers. Shoot growth parameters were less for the air-root-pruned containers, but the volume of this container was half the volume of the other two treatments.

digging and planting time

A number of researchers have shown a strong link between the periodicity of root growth potential and the time of year trees are harvested (59,69,72,73,96,111,140). Generally, the RGP has a slight peak in late summer/early fall and a large peak in late winter/early spring, prior to vegetative bud-break. Research has indicated that difficult-to-transplant species are best transplanted in the spring prior to bud-break (59,69,72,111). Many of these species studied are coarse-rooted with few roots contained in the harvested root ball. In the spring, prior to bud-break, both new root initiation and elongation are taking place allowing the plant to establish at a quicker rate than other times of the year. Witherspoon and Lumis (140) found fall dug-fall planted *Tilia cordata* cultivars had the highest survival and root regeneration rate. Spring dug-spring planted plants, however, were lifted during the period of rapid shoot elongation.

As previously discussed, the periodicty of root growth potential is controlled by the bud dormancy cycle and the reallocation of carbohydrates to elongating shoots. Although most species tend to have a high RGP in late winter/early spring, the exact timing is variable and is dependent on the species, seed source, chilling hours, etc. Monitoring hormone levels in the sap of trees could be an aid to determine when transplanting will be successful (107).

chilling requirement and cold storage

Root initiation and subsequent elongation occurs primarily in the spring in the presence of physiologically nondormant buds (96). The natural bud dormancy which develops during the fall is broken by exposure to chilling temperatures during the winter and early spring. Seedlings that are lifted when buds are not physiologically dormant, or those that have been exposed to enough chilling in the nursery to break bud dormancy, will have RGP decrease while in storage (62). Seedlings that have not received enough chilling and buds are dormant when lifted will continue to release bud dormancy in cold storage and RGP will be increased as chilling hours accumulate. Storage between -2° C and -5° C has given good results with most conifers, provided they are dormant. Tree species adapted to warmer climates may have shorter chilling requirements at higher temperatures or no chilling requirement at all (83).

irrigation/soil moisture

Moisture stress can develop in containerized trees transplanted in the field due to loss of available water from the root ball as a result of drainage by the field soil profile following irrigation (23). To avoid moisture stress the irrigation frequency of a new transplant may need to be even greater than required had it still remained in the container. Trickle irrigation has been shown to be an efficient method of irrigating nursery trees (11,133). The average efficiency of trickle irrigation systems over a two year period ranged from 44% to 72%, as compared with 13% to 20% for overhead sprinklers (133). The pattern of conduction between the roots and leaves of a tree varies between and within species (86). In oaks and other ring pourous species, a given root is directly connected to a particular set of branches usually on the same side of the tree as the root (63). With these types of trees, a symmetrical application of water and fertilizer would be imperative to produce a balanced crown. Abbot and Gough (1), working with blueberries, a plant with minimal lateral transport of water, demonstrated that the non-watered half of the plant exhibited a decrease in all growth characteristics.

Irrigation demand varies among tree species and is closely correlated with monthly potential evapotranspiration rates (100). Fast growing species (red maple, silver maple, boxelder) used the most water over a 3-month experimental period (June through August) compared with slow growing species (sugar maple, Norway maple). Most of the water absorbed by loblolly pine and yellow poplar trees has been shown to enter through suberized roots (65). A number of researchers have shown a positive relationship between trickle irrigation and top and root growth (10,28,53,60,87,88,90,91). Root systems of irrigated trees developed more fibrous roots, yet were distributed in the same volume of soil as non-irrigated trees (87,91). Apple trees developed shallower but more concentrated root systems under wet than dry treatments (10). Roots usually proliferate in moist soil, especially near the surface, partly because moist soil offers low resistance to root expansion and allows for a steep water gradient into expanding root cells (78). Irrigation rates of 2.5 to 5.7 liters/day/plant (90,91) and 25% to 50% replacement of net evaporation (28,87) have been suggested. When using the evaporative pan method adjustments in water supplied to the plant are made during the year based on the actual evaporating canopy size (30).

Klein (61) found that at the period of peak water requirement for peaches and grapes, tensiometers indicated rapid withdrawal of soil water and necessity for daily irrigation. A 12% to14% conservation in water use was accomplished with tensiometers compared with pan evaporation. He concluded that changes in evaporative demand and plant growth and development would influence evapotranspiration rates. Daily watering schedules often do not take into account the rainfall contribution to the soil water status. Overirrigation of peach trees with trickle irrigation resulted in dead roots in the center portion of the wetted volume, with con-concomitant proliferation of roots at the periphery (140). Saturated conditions always results in low soil O_2. Tree species can vary in their response to saturated soil conditions, Pin oak and sycamore trees were adversely affected by saturated soil conditions whereas tupelo gum trees produced maximum growth in saturated soil (27). Green ash grew equally well in saturated soil and under a moisture equivalent regime.

Not much information exists on the effects of irrigation on RGP, although one would suspect that given an increase in fibrous root content one would observe a corresponding increase in RGP with irrigation. Rook (101) determined that seedlings subjected to water stressing for 6 weeks prior to lifting had an increased RGP response compared with unstressed controls. This response was attributed to improved plant moisture balance, apparently resulting from greater stomatal control in the stressed seedlings. Water stress at other times of the year could possibly reduce photosynthate production and decrease the RGP response the following spring.

root restriction and pruning roots

A nursery tree's root system is drastically reduced when harvested, and consequently the amount of soil exploited to gain water and nutrients is reduced to only a small fraction of what it was when undisturbed in the nursery (38,131). To maximize survival, a favorable root:shoot ratio must be re-established rapidly. Root restriction and root pruning are attempts at increasing the amount of absorbing roots moved with transplanted trees. Since only a small portion of roots is moved with a standard sized root ball, a relatively small increase in root surface area could easily double or triple the absorbing surface in the root ball (127). This would mean a greater capacity for water absorption and a potential for increased survival and reduced transplanting shock.

Root restriction often results in decreased plant growth (47,103). The ancient art of bonsai uses root restriction and pruning to aid in dwarfing plants (144). Reduced transport and/or synthesis of gibberellins and cytokinins may be partly responsible for the retarded shoot growth observed in root- restricted plants (18). Root restriction has also been found preferentially to reduce the relative amount of assimilate allocated to the leaves and increase that allocated to the root of the tomato plant (103). The root:shoot ratio of plants grown in smaller containers is generally greater than that of plants grown in large containers (47,103). It is difficult to separate the effects of water stress and fertility from the effect of the more confined root volumes imposed by root restriction. Krizek et al. (66) attributed the increase in root:shoot ratio of soybean plants to increased water-stress and not root restriction. An extensive root system is not necessary for optimum plant growth if a plant can obtain adequate water and nutrients from a restricted zone (119). However, crops with restricted root systems are vulnerable to water stress should rainfall or an irrigation system fail.

In his evaluation of fabric barriers, van de Werken (125,126) found that none suppressed top growth of *Koelreuteria bipinnata*. He concluded that a strong, weld-woven, synthetic fabric with holes of less than .05 in (1.27mm), but no less than .02 in (.5mm), may serve as an effective root barrier for production of pre- balled nursery stock. These specifications would not allow for penetration by large roots, and small penetrating roots would be girdled when they increased in size. In 1983 Reiger and Whitcomb (95) reported on a spun-bonded fabric with a disk of 6-mil polyethylene placed in the bottom of the hole. Whitcomb (137) reported further advancements of the fabric root-restricting container in 1985, and suggested an increased carbohydrate reserves in stem and roots of trees grown in fabric containers compared with those grown without fabric barriers.

Whitcomb (137) argued that fabric root barriers increased the portion of total tree roots harvested, decreased cost and seasonal constraints of conventional tree harvesting, and enhanced tree establishment in the landscape. Claims of up to 80% or more of the plant's root system being retained by the fabric bag (137) and quicker root regeneration (136) following transplanting have been made, yet these figures have not been substantiated with replicated experiments including conventional B&B (balled and burlapped) plants for comparative purposes.

A number of recent studies with fabric barriers were initiated and concluded while this study was in progress (20,55,56,120,121,143). Chong et al. (20) evaluated the effect of fabric containers on the growth of *Populus deltoides* x *nigra*. Unrooted hardwood cuttings were grown in .6, 2.4, 6.0, and 14.0-l fabric containers inserted in 3, 6, 12, and 24-l plastic nursery containers, respectively. Control plants were grown only in plastic containers without fabric containers. Relative proportions of roots in year-old poplar trees retained within the fabric container ranged from 33.6% to 66.4%, for the .6-l to 14.0-l fabric containers, respectively. Overall root growth was less for plants grown in fabric containers when compared to controls, but no differences were found in top growth. Roots outside the fabric container contained more N, P, & K than roots inside the fabric container. Soluble sugar and starch concentrations of roots were greater inside the fabric containers than in roots outside the fabric mesh. One limitation of this study, however, was that the outside volume did not allow for unrestricted root expansion, and therefore may not be representative of actual field conditions.

Ingram et al. (55) maintained that the effects of fabric containers for field production on growth and the portion of the total root system harvested appeared to be species dependent. Of the seven species tested, only live oak and sweet gum roots in the "harvest zone" were increased with fabric containers. Live oak plant height and total carbohydrate content of live oak and magnolia primary root samples were increased by the fabric container. Total carbohydrate content of sweetgum roots was decreased by fabric containers. Root weights were also obtained from outside the harvest zone to determine total root weights, but this only involved a partial excavation (90 cm dia x 36 cm depth) of the root system and is of limited value.

Root pruning studies on small seedlings in the nursery have shown substantial improvements in the root:shoot balance of lifted seedlings (16,102,115,116). Root pruning of landscape-size stock 5 years before transplanting increased the number of roots and the amount of root surface area in the root ball, but reduced top growth (127). The total surface area of the root pruned trees was increased from 122,000 cm^2 to 245,000 cm^2. The root ball of pruned trees contained 11.8% of the total root system compared to 5.8% in root balls of unpruned plants. The root ball was cut 8 inches beyond the point of root pruning, since regenerated roots originate from callus tissue formed near the cut end (130). Gilman and Yeager (40) determined that fibrous root weight was significantly increased in root-pruned live oak trees, and that although regenerated roots tended be concentrated near the root pruned ends, they originated in all areas of the root ball. It is suggested that root pruning be done after plants have completed a flush of growth and when there is adequate supply of soil moisture (24). The exact timing of root pruning is probably closely aligned with the RGP response of each tree species and therefore additional research is required to determine the optimum season and interval between root pruning and harvest. Geisler and Ferree give an in depth review of the response of plants to root pruning (35).

fertilizer

Most of the current fertility research with nursery field production has investigated the effects of nitrogen rates on tree top growth (29,88,89,142). Nitrogen application rates commonly investigated range from 50 to 300 lbs N/A. In actual field production nurseryment normally apply 150 lbs N/A to 300 lbs N/A. The reason the emphasis has been on nitrogen at those application rates is primarly a result of observations obtained with established shade tree studies. These studies are documented in a review by van de Werken (123,124), and they lead to the following conclusions:

1) N is the most important and often the only nutritional element inducing accelerated growth of established shade trees.

2) Surface broadcasting is the most effective application method of nutrients.

3) Fertilizer applications should be based on the radius of the root system.

4) Beneficial application rates of N were found to be between 100 and 400 lbs/A.

5) Broadcast application of a slow-release complete fertilizer is beneficial on phosphorus deficient soils.

Many of the nursery field studies have not demonstrated substantial differences in plant height or plant trunk caliper as affected by higher N levels (56,88,120,142), or fertilizer formulation (21,56). Increasing N from 150 to 300 lbs/A actually decreased 1st and 2nd year plant height and plant trunk caliper of red maple (142).

Due to the limited top growth response of nursery trees to fertilizers the effects of mineral fertilizers on root growth has often been ignored. Pounder et al. (88) demonstrated that applying 180 lbs N/A resulted in the greatest concentration of roots within the root ball of red maple trees and had little affect on top growth. The increase in roots was mainly due to the presence of larger quantities of primary and secondary roots. Gough (42) found that the root balls of blueberries plants were more dense on the fertilized side than on the unfertilized side. Studies with fruit trees have also showed similar results (5,108). Overfertilization with nitrogen, however, can reduce the concentration of feeder roots in the principal rooting zone of citrus trees (34).

Results from pine seedling research showed that when seedling nutrition is manipulated in the nursery a large shoot growth response is accompanied by only a relatively small response in the root system, particularly in relation to the root number, distribution and length of different root members (81). Consequently, high fertility in the nursery can lead to an undesirable root:shoot ratio in seedlings. Nitrogen fertilization has also been shown to affect mycorrhizal formation negatively (79). The observation that high soil fertility decreases mycorrhizas has practical implications because the rates of fertilizers used in nursery production are generally high (81). Mycorrhizas can be considered as an extension of the root network and their abundance on seedlings grown under low fertility would compensate to a large extent for any increase in total root length from higher fertility levels.

other factors

Top pruning will reduce root growth either by reducing photsynthesis or by diverting hormones and carbohydrates to the shoots (64). Reducing the photosynthetic surface is undersirable except for those times when water conservation (64), or maintenance of plant form is more important (134). Whitcomb (134,135) maintains that good stem taper is favored by the presence of lower branches, and they consequently should be retained until one year before harvest time. Removal of lower limbs is usually accomplished during the dormant season.

Trees should always be spaced to allow for good growth and development relative to the time of harvest. Trees expected to be harvested when they have a two-inch caliper are properly spaced between 30 and 48 inches, while proper spacing for three-inch caliper trees is between 60 to 84 inches (135). Orchard tree roots at higher planting densities make greater use of the subsoil at a much earlier age than wider tree spacings (6).

Root growth is restricted by low soil oxygen supply (42) and mechanical impedance due to soil compaction (7,39,85). Some general bulk densities (g/cc) that will impede root growth in moist soil are 1.55 for clay loams, 1.65 for silt loams, 1.80 for sand loams, and 1.85 for loamy sands (13). Soil compaction can result in reduced root development in lower soil profiles (39).

Effects of transplanting practices on expression of root growth potential.

Proper nursery cultural practices can greatly enhance RGP in nursery trees, yet improper handling and transplanting in unsatisfactory soil conditions will subsequently reduce RGP. Proper preparation of the planting site is imperative to provide a favorable environment for root growth after transplanting. Watson (128) maintains that reduction of the severity and duration of plant stress following transplanting can be achieved by modifying the planting hole to encourage fine root development in the shallow, well aerated back fill soil. This can be accomplished by enlarging the top of the hole (39,51) and progressively sloping the sides towards the base of the root ball at a more oblique angle (128). Since the diameter of the hole decreases with depth, effort is concentrated in the upper soil layers which are most favorable for root growth.

Soil water can often be excessive and oxygen unavailable in sufficient quantities to support root growth (9). Planting in dense compacted soils will allow for easy water infiltration into the back fill soil with it abruptly slowing down at the subsoil- back fill interface. The planting hole can become water-logged and suffocate the root system. Hammerschlag and

Patterson (46) recommend placing the root ball on a pedestal of compacted soil to avoid settling, and to elevate the root ball out of the wet soil at the bottom of the hole.

Limited available soil water is often the problem on well-drained planting sites and areas with little rainfall. Barnett (8) demonstrated that maximum establishment and plant growth are obtained with frequent irrigations. Lateral root extension made 14.3-l of water available to frequently irrigated (every 5th day) plants, compared to only 6.5-l for the infrequently irrigated (every 10th day) plants. Conditions leading to water stress are avoided by frequent irrigations, and the root systems will expand rapidly making more water available to the plant in order that the intervals between irrigations can be lengthened.

Circling and girdling roots are suspected of stunting growth and increasing susceptibility to wind breakage and blowdown (43,44,122). To correct this problem it is often suggested that the root ball be disturbed by cutting and "butterflying" (43,44). In contrast, most of the data obtained from transplant studies have found, that girdling has not been detrimental to the early growth of trees, and disturbing roots is not beneficial (3,12,68,139). Long-term growth of Norway maple trees was not affected by girdling roots (118). Comparison of total heights, crown diameters and diameter (at breast height) showed no significant difference in accumulated growth over the 50-year life span of girdled and non-girdled trees.

Addition of soil amendments to the back fill soil, and top pruning of trees at the time of transplanting are still commonly practiced by many landscapers. Research in this area has indicated that traditional backfill amendments are not necessary (22,36,57,58) and severe pruning of tree tops will repress root growth (37,54,70).

Tree size can have a profound affect on the duration of transplanting stress and the length of time necessary to replace that portion of the root system lost during transplanting (1,127). Following transplanting, four-inch diameter trees will exhibit slow growth, and smaller 1 inch to 3 inch trees transplanted at the same time, will often surpass or equal the larger trees in growth. Root regeneration occurs laterally from the perimeter of the root ball, and growth rate of regenerated roots is essentially the same for both large and small unstressed trees of transplantable size. By crop modeling, Watson (127) demonstrated that a 4 inch diameter tree will replace its original root system in less than five years assuming 18 inches per year lateral root growth and 2% of the original soil root volume retained after transplanting. After five years, the regenerated root system of a 10 inch diameter tree will be only 25% of its original size, and the tree remains stressed. A period of 13 years or more is required to restore the original balance of the 10 inch tree.

Materials and Methods

Four field studies with fabric field containers were conducted at Burden Research Plantation, Louisiana State University Agricultural Center, Baton Rouge, LA in a fine-silty, mixed thermic aquic, Fraguidalf soil (Olivier silt loam). Soil analysis of the experiment site indicated the following initial nutrient levels (ppm): P, 29; K, 84; Ca, 1084; Mg, 303; organic matter, 0.6%; and a soil water pH of 5.9 (14).

The four studies evaluated the following treatment combinations: *Expt. 1*, Production methods and irrigation; *Expt. 2*, Fertilizer formulation and irrigation; *Expt. 3*, Fabric field container size, irrigation, and fertilizer application method; and *Expt. 4*, Rate of slow release fertilizer. Uniform 3.8-l (1 gal.) container-grown liners of *Acer rubrum* (red maple), *Betula nigra* (river birch), *Pinus Elliotti* (slash pine), *Quercus virginiana* (live oak), and *Taxodium distichum* (bald cypress) were transplanted in each of the studies. Trees were spaced 1.22 m (4 ft) within and 1.83 m (6 ft) between rows [4,485 trees/ha (1,815 trees/A)]. All trees were pruned to a single trunk except *Betula nigra* which was maintained as a multi-trunk with three stems.

Pre-emergent control of weeds was accomplished by a direct spray application of Oryzalin 4AS (surflan[1]) at a rate of 2.2 kg ai/ha (2 lb ai/A) in April and July of every year. Prior to pre-emergent application, all existing

1 Elanco Products Co., Lafayette, LA

weeds were removed by a direct spray application of Paraquat[2] at a rate of 0.6 kg ai/ha (0.5 lb ai/A), and after sufficient weed death occurred the soil was lightly tilled between rows. A few lower branches of each tree were removed prior to the July 1986 and July 1987 spraying to aid with application of herbicides.

Trickle irrigation was installed 8 May, 1985 using two pressure compensating emitters [1.9-l (0.5 gal)/hr/emitter] placed 15.2 cm (6 inches) on each side of the tree trunk. Water was applied to each tree at a rate of 1.9-l (0.5 gal) every 2 days (May 1985), 4.7-l (1.25 gal) every 3 days (June 1985 through May 1986), 7.7-l (2.0 gal) every 3 days (June 1986 to November 1986), and 11.4-l (3 gal) every 3 days (March 1987 to Nov. 1987). Plant canopy diameters of 0.45, 0.61, 0.76, and 0.91 meters (1.5, 2.0, 2.5, and 3.0 ft) were used to calculate water application rates of 100% of net pan evaporation [0.5 cm (0.2 in)/day] as outlined by Shepersky (105). Irrigation was not applied for two irrigation cycles if cumulative rainfall exceeded 2.54 cm(1 in) and for one irrigation cycle if accumulative rainfall exceeded 1.27 cm (0.5 in) for the period preceeding an irrigation. The irrigation cycle was delayed up to 1 day when there was a threat of rain on the scheduled irrigation day, or when precipitation was less than 1.27 cm (0.5 in). Irrigation was not applied from Dec through Feb and after Nov, 1987. Overhead irrigation [1.3 cm (0.5 in)] was applied to all trees on 28 May, 1985 and 28 June, 1985 to assure survival of non-irrigated trees. Irrigation and rainfall data are presented in Tables 1, 2 and 3.

2 Ortho , Chevron Chemical Co., Memphis, TN

Experiment 1. Three plant production methods: flat bed, raised bed, and flat bed with 46 cm (18 in) diameter fabric Field-Grow containers (Root Control, Inc., Oklahoma City, OK) were placed within trickle irrigated and nonirrigated plots. Five species were transplanted on 17 April, 1985. The experimental design was a split-split plot with 5 replications and two single tree subsamples. Irrigation treatments comprised the main plots, with planting methods as the sub-plots, and species as the sub- sub-plot. Planting holes [33 cm (13 in) depth] for the flat bed and fabric field container treatments were prepared using a 46 cm (18 in) diameter auger. Raised beds, were 0.6m (2 ft) wide at the base and 0.3 m (1 ft) high. A 13N-5.5P-10.7K (13N-13K_20-13P_20_5) granular fertilizer[3] was applied at the rate of 168 kg/ha/yr (150 lb N/A/yr) divided into 3 equal applications. The fertilizer was top-dressed in a circular pattern [30 cm (12 in) diameter] around each tree in April, June and August.

Trunk caliper (at 15.2 cm height) and plant height measurements were made during the week of 16 April, 1986 (1 year) and 16 April, 1987 (2 years). All trees were harvested on 16 April, 1987. Trees from flat and raised bed treatments were extracted from the soil with a 61 cm (24 in) tree spade [(65.1-l) 2.3 ft^3] then balled and burlapped. Trees in fabric field containers [(53.8-l) 1.9 ft^3] were harvested with a 81 cm (32 in) tree spade and the soil surrounding the fabric container was manually removed. B & B trees were placed in a protective wire basket. One tree sub-sample of each replicate was sacrificed to obtain root dry weights and a root rating within the harvested root ball.

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3 Bonus Crop Fertilizer, Inc., Houston, TX

The other tree sub-sample was transported to an outdoor limestone bed area with overhead irrigation and maintained in full sun for 30 to 35 days, after which time it was transplanted into a 114-l (30 gal) container and extracted 60 days later to determine root growth potential. Fabric field containers were removed prior to transplanting. Trees were irrigated every other day with 1.3 cm (0.5 in) of water through low volume spray emitters. Only those new roots growing into the artificial medium were harvested, washed and dry weights determined. The medium consisted of 100% pine bark amended with 1.19 kg N/m^3 (2 lb N/yd^3) of Osmocote[4] 18N-2.5P- 9.9K (18N-6P_2O_5-12K_2O), 3.56 kg/m^3 (6 lb/yd^3) dolomite, and 0.89 kg/m^3 (1.5 lb/yd^3) Micromax[4].

Experiment 2. Five tree species were transplanted to 46 cm (18 in) diameter fabric field containers on 17 April, 1985. Four fertilizer treatments: Osmocote 17N-2.9P-9.9K (17N-7P_2O_5-12K_2O); Osmocote 24N-1.7P-5.0K (24N-4P_2O_5-6K_2O); Woodace 14N-1.3P-2.5K (14N-3P205-3K_2O) briquettes; and an inorganic 13N-5.7P-10.7K (13N-13P_2O_5-13K_2O) granular fertilizer were placed within trickle irrigated and non-irrigated plots. The experimental design was a split-split plot with six replications. Irrigation treatments comprised the main plots, with species as the sub-plots, and fertilizer treatments as the sub-sub-plots.

Fertilizer was applied to provide for a yearly nitrogen release rate of 168.5 kg/ha (150 lb/A). The granular fertilizer was applied as in *Expt. 1.* The slow release fertilizers were banded 5 cm (2 in) below the surface in a circular pattern [30 cm dia. (12 in. dia.)] around each tree during the

4 Sierra Chemical Co.(Milpitas, CA

transplanting of liners. Osmocote 24-4-6 and Woodace 14-3-3 have a longevity of 18 months so their nitrogen application rates were increased by 1.5 times to provide for the same anticipated yearly nitrogen release as the 12 month Osmocote 17- 7-12. The same fertilizer rates were re-applied for Osmocote 17-7-12 on 20 Feb, 1986 and for the Woodace 14-3-3 and Osmocote 24-4-6 fertilizers six months later on 20 Aug, 1986. Osmocote fertilizers were re-applied to two dibbles placed 15 cm (6 in) on either side of the tree, whereas the Woodace fertilizer required four dibbles placed 15 cm (6 in) from the tree, one in each quadrant.

Actual application rates for the slow release fertilizers were 221 g/tree, 234 g/tree, and 402 g/tree (25 briquettes/tree) for Osmocote 17-7-12, Osmocote 24-4-6 and Woodace 14-3-3, respectively. The granular fertilizer was applied at a rate of 96 g/tree, three times a year during 1985 and 1986. Trunk caliper and plant height measurements were made during the week of 16 April, 1986 (one year) and 16 April, 1987 (two years).

Experiment 3. Two fabric field container sizes: 46 cm (18 in) diameter by 33 cm (13 in) depth [53.8-l (1.9ft^3)] and 61 cm (24 in) diameter by 38 cm (15 in) depth [110-l (3.9 ft^3)] were placed within trickle irrigated and non-irrigated plots. Five tree species were transplanted to the fabric field containers 24 April, 1985 and Osmocote 17N-2.9P-0.9K (17N-7P_2O_5-12K_2O) was top-dressed and dibble applied at a rate of 168 kg N/ha (150 lbs N/A). Fertilizer was reapplied at the same rate on the week of 16 April, 1986. No further applications were made after this date. The dibble treatments were applied as in *Expt. 2*, and the top-dressed treatments as in *Expt. 1*. The experimental design was a split-split-split plot with six replications. Irrigation treatments comprised the main plots, with fabric container size as the sub-plots, species as the sub- sub-plots, and fertilizer application method as the sub-sub-sub plot. Trunk caliper and plant height measurements were made during the week of 16 April, 1986 (one year), 16 April, 1987 (2 years), and 16 April, 1988 (3 years). Root dry weights were determined on 16 April, 1988 (3 years) for harvested root balls of *Pinus Elliotti* (slash pine) and *Acer rubrum* (red maple) from treatments with dibble-applied fertilizer.

Experiment 4. Four rates of Osmocote 17N-2.9P-9.9K (17N-7P_2O_5-12K_2O): 84 kg N/ha (75 lb N/A), 168 kg N/ha (150 lb N/A), 252 kg N/ha (225 lb N/A), and 336 kg N/ha (300 lb N/A) were evaluated for six species of trees. *Liriodendron tulipifera* (Tulip poplar) was included in addition to the other five tree species. The experiment was initiated on 29 April, 1985. All trees were planted in 46 cm (18 in) diameter fabric field containers and trickle irrigated. Fertilizer was dibble applied as in *Expt. 2* and reapplication was made during the week of 16 April, 1986. The experimental design was a completely randomized design with four fertilizer rates and eight replications. Trunk caliper and plant height were measured during the week of 16 April, 1986 and 16 April, 1987. Statistical analysis of resutls were performed separately for each species.

Table 1. Irrigation and rainfall data for 1985/1986 season (1st year).

	Trickle irrigation							
	No. applications	Application rate l/tree (gal/tree)		Water applied l/tree (gal/tree)		Rainfall cm (inches)	
1985							
Apr[z]	10	---------		--------		.53	(.21)
May	10	1.89	(.50)	18.9	(5.00)	.48	(.19)
June	8	4.73	(1.25)	37.9	(10.00)	2.36	(.93)
July	5	4.73	(1.25)	23.7	(6.25)	14.10	(5.55)
Aug	2	4.73	(1.25)	9.5	(2.50)	18.29	(7.20)
Sept	4	4.73	(1.25)	18.9	(5.00)	13.64	(5.37)
Oct	7	4.73	(1.25)	33.1	(8.75)	21.84	(8.60)
Nov		---------		--------		10.90	(4.29)
1986							
Jan		---------		--------		4.09	(1.61)
Feb		---------		---------		16.00	(6.30)
Mar	7	4.73	(1.25)	33.1	(8.75)	6.60	(2.60)
Apr[y]	4	4.73	(1.25)	18.9	(5.00)	2.16	(.85)
		Total		212.9	(56.25)[x]	112.60	(44.33)

[z] April 17 through April 30, 1985. Heavy rainfall on 28 April, 1985 not recorded.
[y] April 1 through April 16, 1986
[x] Equivalent to 9.55 cm (3.76 in.) supplemental irrigation based on plant area of 2.23 m^2 (24.0 ft^2).

Table 2. Irrigation and rainfall data for 1986/1987 season (2nd year).

	Trickle irrigation			
	No. applications	Application rate l/tree (gal/tree)	Water applied l/tree (gal/tree)	Rainfall cm (inches)
1986				
Apr[z]	3	4.73 (1.25)	14.2 (3.75)	4.70 (1.85)
May	4	4.73 (1.25)	18.9 (5.00)	11.35 (4.47)
June	1	7.57 (2.00)	7.6 (2.00)	18.29 (7.20)
July	5	7.57 (2.00)	53.0 (14.00)	6.05 (2.38)
Aug	7	7.57 (2.00)	53.0 (14.00)	6.05 (2.38)
Sept	8	7.57 (2.00)	60.6 (16.00)	3.40 (1.34)
Oct	5	7.57 (2.00)	37.9 (10.00)	11.51 (4.53)
Nov	1	7.57 (2.00)	7.6 (2.00)	43.94 (11.61)
Dec	------	---------	---------	8.00 (3.15)
1987				
Jan	------	----------	---------	30.09 (7.95)
Feb	------	----------	---------	33.31 (8.80)
Mar	4	11.36 (3.00)	45.4 (12.00)	12.85 (5.06)
Apr[y]	4	11.35 (3.00)	45.4 (12.00)	2.72 (1.07)
	Total		328.35 (86.75)[x]	169.95 (66.91)

[z] April 17 through April 30, 1986
[y] April 1 through April 16, 1987
[x] Equivalent to 14.73 cm (5.80 in) supplemental irrigation based on plant area of $2.23 m^2$ ($24.0 ft^2$)

Table 3. Irrigation and rainfall data for 1987/1988 season (3rd year).

	Trickle irrigation			
	No. applications	Application rate l/tree (gal/tree)	Water applied l/tree (gal/tree)	Rainfall cm (inches)
1987				
Apr[z]	5	11.36 (3.00)	56.8 (15.00)	0.00 (0.00)
May	4	11.36 (3.00)	45.4 (12.00)	14.25 (5.61)
June	2	11.36 (3.00)	22.7 (6.00)	27.46 (10.81)
July	4	11.36 (3.00)	45.4 (12.00)	8.99 (3.54)
Aug	3	11.36 (3.00)	34.1 (9.00)	27.66 (10.89)
Sept	6	11.36 (3.00)	68.1 (18.00)	5.89 (2.32)
Oct	8	11.36 (3.00)	90.8 (24.00)	2.95 (1.16)
Nov	9	11.36 (3.00)	102.2 (27.00)	1.78 (.70)
1988				
Jan	-------	----------	---------	8.84 (3.48)
Feb	-------	----------	---------	34.87 (13.73)
Mar	-------	----------	---------	21.79 (8.58)
Apr[y]	-------	----------	---------	9.30 (3.66)
	Total		465.56 (123.00)[x]	170.13 (66.98)

[z] April 17 through April 30, 1987
[y] April 1 through April 16,1988
[x] Equivalent to 30.88 cm (8.22 in.) supplemental irrigation based on plant area of 2.23 m^2 (27.0 ft^2).

Results and Discussion

Experiment 1. Planting method did not influence plant height or trunk caliper for *Acer, Pinus, Quercus,* and *Taxodium* (Table 4). *Betula* plant height was significantly decreased by the fabric bag compared with flat bed (Table 6).

Trickle irrigation had a positive influence on plant height and trunk caliper after one and two years for all species (Table 4). The average increase in plant height was 16 cm (6.3 in) and 21 cm (8.3 in) after one and two years, respectively. The average increase in trunk caliper was only 0.26 cm (0.1 in.) and 0.35 cm (0.14 in.) after one and two years, respectively. Similar effects of trickle irrigation on top growth were reported by Tilt & Dickerson (121).

The tallest species after two years was *Betula*, whereas *Taxodium* and *Pinus* produced the largest trunk caliper (Table 4). Trunk calipers for *Taxodium* and *Pinus* were at least 2.54 cm (1 in.) greater in diameter compared with the other species after two years. *Betula* averaged over 50 cm (20 in) greater height than the other species, after two years.

Fabric bags and trickle irrigation increased the number of fibrous roots and the root mass within the harvested root ball (Table 5). Interactions between planting method and species were significant for root dry weight and root mass density (Table 6). Significant increases in harvested root dry weights were obtained with fabric bag treatments for *Acer, Pinus* and *Taxodium*. *Betula* root dry weights were not different and *Quercus* root dry weights were significantly greater for fabric bag and raised bed treatments. The harvested root zone of the fabric bag was 17% smaller than the B & B treatments (flat bed and raised bed), yet the average root dry weights were higher for all species. Comparisons of root dry weights based on volume (root mass density) showed significant increases with fabric bag treatments for all species (Table 6). Fabric bags resulted in a 65% to 76% (*Acer*), 32% to 39% (*Betula*), 97% to 110% (*Pinus*), 25% to 80% (*Taxodium*) increase in root mass density. Root ratings for fabric bag treatments were significantly greater than B & B treatments. Fibrous roots were increased with the fabric bag but most of the increase in root weight could probably be attributed to the increase in primary root growth within the harvested root ball.

Trickle irrigated plants produced significantly higher root ratings, root dry weights, and root mass densities within the harvested root ball for all species and planting methods (Table 5). Root dry weights were 28% higher for irrigated plants compared to non-irrigated. Fibrous roots increased with irrigated plants, as indicated by the higher root rating. These data indicate that trickle irrigation could enhance survivability of transplanted field-grown trees. Survival differences were not seen after transplanting but exposure to a more stressful environment during the postharvest period than experienced by trees in this experiment could result in survival differences.

The *Betula* harvested root ball had the highest root dry weights of all species (Table 5). *Pinus* and *Taxodium* developed the second greatest root dry weights. The fibrous root systems of *Acer* and *Quercus* tended to be fragile and difficult to maintain intact when removing the soil by washing.

Harvested root dry weights were lowest for *Acer* and *Quercus* but their actual values were probably deflated more so than the other species due to loss during soil removal.

Interaction between planting method and species were significant for root growth potential (RGP) measurements (Table 6). Fabric bags significantly increased RGP for *Taxodium* compared with B & B treatments, but decreased RGP for *Acer* compared with raised beds. Raised bed treatments reduced RGP for *Pinus* compared with fabric bags or flat bed treatments. RGP for *Betula* and *Quercus* were not affected by planting method.

It is interesting to note that fabric bags increased root dry weight and fibrous root content of the harvested root balls for *Acer, Quercus,* and *Pinus,* yet a corresponding increase in RGP was not observed. Removal of the fabric bag was done prior to transplanting and the integrity of the root ball could not be maintained for *Acer* and *Quercus*. Much of the improvement in root mass was negated because the root ball fell apart. The removal of the fabric bag also damaged many of the white newly intiated roots on the surface of those root balls remaining intact. Yadav et al (143) also found that with live oaks it was difficult to remove the fabric bag without disturbing the roots.

Survival of trees during the postharvest period and after transplanting was not affected by planting method. All trees survived this period. Trees from fabric bag treatments with root balls that remained intact during transport did exhibit fewer water stress symptoms and leaf drop; however, these observations were not quantified. The increased root mass in fabric bags may offer some advantages under more stressful conditions. The problem with the fabric bag may be in keeping the root system intact during transport. Trees in this experiment were handled with great care and were not stacked or handled as roughly as they would be in a typical nursery situation, yet many of the *Acer* and *Quercus* root balls were easily disturbed. B & B treatments were placed in wire baskets and could withstand more abuse than fabric bags.

Main effects of irrigation on root growth potential (RGP) were not significant (Table 5). Species main effects were significant for RGP. RGP was greatest for *Acer*, yet the root dry weight obtained within the harvested root ball was low. The test for RGP was done during the period of rapid shoot development and species vary in their ability to regenerate roots after transplanting during this period. A simple linear relationship between increased root growth within the harvested root ball in fabric bags and increased RGP did not exist. Disturbance of the root ball with removal of the bag can negate any advantages the fabric bag may offer and each species' internal controls will have a big influence on expression of RGP. Flat bed and raised bed root systems were unrestricted and their roots were severed during the harvesting process. The ability to regenerate roots from severed ends can vary seasonally and is unique for each species. It is not known if similar seasonal patterns of RGP for each species exist between severed unrestricted root systems and non-severed restricted root systems.

Table 4. Main effects of irrigation, planting method, and species on plant height and trunk caliper after one and two years, *Expt. 1.*

	1st Year				2nd Year			
Treatment	Plant ht(m)		Trunk caliper(cm)		Plant ht(m)		Trunk caliper(cm)	
Irrigation, I								
Irrigated	2.30		3.63		3.19		5.24	
Not irrigated	2.14		3.37		2.98		4.89	
Planting Method, P								
Fabric bag	2.21		3.49		3.06		5.07	
Flat bed	2.28		3.61		3.14		5.06	
Raised bed	2.17		3.40		3.05		5.06	
Species, S								
Acer rubrum	2.37	a[z]	3.11	b	2.97	b	4.04	b
Betula nigra	2.48	a	2.66	c	3.55	a	3.72	b
Pinus Elliotti	2.00	c	4.48	a	2.91	b	6.84	a
Quercus virginiana	2.17	b	2.85	c	3.05	b	3.92	b
Taxodium distichum	2.08	bc	4.40	a	2.96	b	6.80	a
Main effects								
Irrigation	**		**		**		**	
Planting method	NS		NS		NS		NS	
Species	**		**		**		**	
Interactions	NS		NS		PXS*		NS	

[z] Mean separation within main effects and columns by Duncan's multiple range test, 5% level.

**, *, NS Significant at 1% and 5% levels and not significant, respectively.

Table 5. Main effects of irrigation, planting method, and species on root growth of two year harvested rootball and root growth potential, *Expt. 1*.

Treatment	Harvested Root Ball: Root rating[z]		Harvested Root Ball: Root dry wt (g)		Harvested Root Ball: Root mass denisty ($g \cdot liter^{-1}$)		Root Growth Potential: root dry wt (g)	
Irrigation, I								
Irrigated	7.3		1807		30.3		37.2	
Not irrigated	6.1		1414		23.5		33.6	
Planting method, P								
Fabric bag	8.7	a	2017	a	37.5	a	37.9	
Flat bed	5.5	b	1382	b	21.2	b	34.0	
Raised bed	5.9	b	1434	b	22.0	b	34.2	
Species, S								
Acer rubrum	7.2	a	1198	d	20.0	d	70.1	a
Betula nigra	6.9	ab	2568	a	42.4	a	49.9	b
Pinus Elliotti	6.5	c	1819	b	30.6	b	32.0	c
Quercus virginiana	6.7	bc	960	d	15.9	d	7.9	e
Taxodium distichum	6.0	d	1509	c	25.6	c	17.0	d
Main effects								
Irrigation	**		*		*		NS	
Planting method	**		**		**		NS	
Species	**		**		**		**	
Interactions	NS		PXS*		PXS*		PXS**	

[z] Based on a scale of 1-10 (1 = lowest fibrous & total root mass, 10 = highest fibrous & total root mass)

[y] Mean separation within main effects and columns by Duncan's multiple range test, 5% level.

**, *, NS Significant at 1% and 5% levels and not significant, respectively.

Table 6. Interactions of planting method and species on 2nd year plant height, harvested root dry weight, root mass density and root growth potential, *Expt. 1.*

Planting method	SPECIES *Acer rubrum*		*Betula nigra*		*Pinus Elliotti*		*Quercus virginiana*		*Taxodium distichum*	
	2nd year plant height (m)									
Fabric bag	2.88	a[z]	3.33	b	2.95	a	3.17	a	2.99	a
Flat bed	2.99	a	3.81	a	2.92	a	2.96	a	3.11	a
Raised bed	3.10	a	3.50	ab	2.84	a	3.00	a	2.79	a
	Harvested root dry wt (g)									
Fabric bag	1482	a	2763	a	2488	a	1093	a	2256	a
Flat bag	1022	b	2409	a	1529	b	734	b	1215	b
Raised bed	1090	b	2532	a	1440	b	1053	a	1055	b
	Harvested root mass density ($g \cdot liter^{-1}$)									
Fabric bag	27.6	a	51.4	a	46.3	a	20.3	a	41.9	a
Flat bed	15.7	b	37.0	b	23.5	b	11.3	c	18.7	b
Raised bed	16.7	b	38.9	b	22.1	b	16.2	b	16.2	b
	Root growth potential, root dry wt (g)									
Fabric bag	56.3	b	54.6	a	36.3	a	7.7	a	34.7	a
Flat bed	73.5	ab	46.9	a	38.1	a	5.9	a	5.6	b
Raised bed	80.5	a	48.1	a	21.6	b	10.0	a	10.6	b

[z] Mean separation within columns by Duncan's multiple range, 5% level.

Experiment 2. All trees were grown in 46-cm-diameter fabric bags and top growth of all five species responded to trickle irrigation (Table 7). Plant height was significantly greater after one and two years for irrigated plants compared to non-irrigated plants. Trunk caliper was significantly greater after one year for irrigated plants. The average increase in trunk caliper was 0.19 cm (0.07 in) and 0.36 cm (0.14 in) for one and two years, respectively. The small increases in plant height and trunk caliper would be of no economic value. Trickle irrigation effects on root growth were not examined.

Fertilizer formulation had no affect on plant height or trunk caliper for years one or two (Table 7). Ingram (56) also observed no differences of top growth of fabric bag-grown trees as influenced by fertilizer sources.

Trunk caliper was highest for *Taxodium* after one and two years, followed in ranking by *Pinus*. *Betula* produced the greatest plant heights after one and two years. These results were similar to those found in *Expt. 1*.

Table 7. Main effects of irrigation, planting method, species, and fertilizer on plant height and trunk caliper after one and two years, Expt. 2.

Treatment	1st Year Plant ht(m)	1st Year Trunk caliper(cm)	2nd Year Plant ht(m)	2nd Year Trunk caliper(cm)
Irrigation				
Irrigated	2.33	3.69	3.18	5.19
Not irrigated	2.23	3.50	3.05	4.83
Species				
Acer rubrum	2.30 b[z]	2.97 c	2.91 c	3.93 c
Betula nigra	2.59 a	2.85 c	3.74 a	4.04 c
Pinus Elliotti	1.93 c	4.29 b	2.47 d	5.86 b
Quercus virginiana	2.30 b	2.80 c	3.18 b	3.93 c
Taxodium distichum	2.30 b	5.08 a	3.29 b	7.32 a
Fertilizer				
Granular (13-13-13)	2.31	3.59	3.12	4.95
Osmocote (17-7-12)	2.26	3.69	3.10	5.04
Osmocote (24-4-6)	2.28	3.56	3.13	4.96
Woodace (14-3-3)	2.29	3.55	3.12	5.08
Main effects				
Irrigation	*	**	**	NS
Species	**	**	**	**
Fertilizer	NS	NS	NS	NS
Interactions	NS	NS	NS	NS

[z] Mean separation within main effects and columns by Duncan's multiple range test, 5% level.

**, *, NS Significant at 1% and 5% levels and not significant, respectively.

Experiment 3. The effects of irrigation, fabric bag size, species, and fertilizer application method were evaluated in this study. Species effects were significant, as were SXBXI, SXI, AXS, AXB, and AXI interactions (Table 8). Interactions between application method and fabric bag size occurred on first year plant height and first, second, and third year trunk caliper (Table 9). The general trend was for dibble applied fertilizer to be more effective with the 46-cm-diameter fabric bags and the top-dressed applied fertilizer to be more effective with the 61-cm-diameter fabric bags. Heavy rainfall floated much of the Osmocote fertilizer of top-dressed treatments outside the perimeter of the 46-cm-diameter fabric bag. This resulted in less fertilizer in the area of the restricted root zone. Top-dressed fertilizer remained within the perimeter of the 61-cm-diameter fabric bag and the root system, being less restricted, was not as concentrated near the dibble applied fertilizer. Dibble application in 46-cm-diameter fabric bags resulted in an average increase of 0.32 cm (0.13 in.) for third year trunk caliper whereas top-dress application in 61-cm-diameter fabric bags resulted in an average increase of 0.49 cm (0.19 in.) for third year trunk caliper.

Application method by irrigation interactions were only significant for third year trunk caliper (Table 10). When irrigated, dibble applied treatments showed an average decrease of 0.5 cm (0.20 in.) compared to irrigated topdress treatments. Non-irrigated dibble and top-dressed treatments resulted in a 0.39 cm (0.15 in.) increase and 0.44 cm (0.17 in.) decrease compared to their irrigated counterparts, respectively. Excessive leaching from irrigation may have been responsible for reducing nutrient levels below optimum for dibble applied treatments and a corresponding reduction in third year trunk caliper. The longevity of Osmocote was probably increased by surface application and residual levels on the soil surface may have remained high into the third year. Nutrient release of residual top-dressed fertilizer in the third year may have benefitted from the minimal soil surface wetting provided for by trickle irrigation.

Species responded differently from each other to application method during the third year of growth (Table 11). *Acer* on the average tended to benefit from dibble application and *Pinus* from top-dressed application. *Acer* average trunk caliper declined 0.88 cm (0.35 in.) when top-dressed and *Pinus* average trunk caliper increased 0.74 cm (0.30 in.) when top-dressed.

Irrigation resulted in decreased plant height (2nd and 3rd year) for *Acer* and *Pinus*, and increased plant height for *Betula, Quercus,* and *Taxodium* (Table 12). Third year trunk caliper for *Pinus* in 46-cm-diameter fabric bags was significantly reduced by irrigation, compared with non-irrigated trees (Table 13). Reduction of 1.65 cm (0.65 in.) trunk caliper resulted from irrigation of *Pinus* in 46-cm-diameter fabric bags. *Betula* and *Taxodium* trunk caliper increased with irrigation regardless of fabric bag size. The increase was greatest within the 61-cm-diameter bag for *Betula* and the 46-cm-diameter bag for *Taxodium*. Trickle irrigation resulted in significant decreases in root dry weights of 3-year-old harvested root balls of dibble- fertilized *Acer* and *Pinus* (Table 14). These data and observations demonstrate that trickle irrigation may not be beneficial to all field grown nursery stock, especially in areas of limited drainage and high rainfall. Watering based on replacement of net evaporation does not take into account the internal drainage characterstics of a particular soil or the changes in evaporative demand influenced by plant growth and development.

Root dry weights of trees grown in 61-cm-diameter fabric bags were not different from those grown in 46-cm-diameter fabric bags for *Acer* and *Pinus* trees grown with dibbled-applied fertilizer. Primary roots in the 61-cm-diameter fabric bag appeared to be thinner and longer than primary roots in the 46-cm-diameter fabric bag. These observations suggest that the total root length may be quite different for each fabric bag size. Increased total root length length and internal root extension into the greater soil volume of 61-cm-diameter fabric bags would increase the amount of water available to the tree, and stress after harvesting could be reduced prior to and after transplanting.

The manufacturer of fabric bags recommends 5.1-cm-diameter caliper trees be harvested in 46-cm-diameter fabric bags and 7.6-cm-diameter caliper trees in 61-cm-diameter fabric bags. This recommendation provides for soil volumes of approximately 20% less than American Association of Nurserymen specifications for B & B trees (2). The top growth rate (plant height and trunk caliper) varied between species grown in fabric bags (Fig 1 and Fig 2). Predicted lengths of time to reach 5.1-cm-diameter trunk caliper for fabric bag grown trees are approximately 1.5, 1.75, 2.5, 2.75 and 3.0 years for *Taxodium, Pinus, Betula, Acer,* and *Quercus*, respectively (Fig 2). The variations in growth rates of species makes it extremely difficult to coordinate the optimal harvesting time with the peak sales period. Tree spade size can be manipulated to adjust for trunk caliper size, allowing for more versatility during harvesting. With fabric bags the opportunity to harvest plants at an earlier age and smaller trunk caliper is not possible since you are locked into a specific tree size and soil volume. Nurserymen often plow up and burn overgrown unsold trees that become unmanageable. Trees that are not sold and outgrow the fabric bag would present a problem since the bag still would remain in the ground.

Table 8. Main effects of irrigation, fabric bag size, species, and fertilizer application method on plant height and trunk caliper after one, two and three years, *Expt 3.*

	1st year		2nd year		3rd year	
	Plant ht(m)	Trunk caliper(cm)	Plant ht(m)	Trunk caliper(cm)	Plant ht(m)	Trunk caliper(cm)
Irrigation, I						
Irrigated	2.27	3.59	3.08	4.96	4.54	7.39
Not irrigated	2.28	3.64	3.09	4.90	4.50	7.36
Bag size, B						
46-cm	2.31	3.67	3.12	4.98	4.55	7.44
61-cm	2.25	3.56	3.06	4.89	4.49	7.31
Species, S						
Acer rubrum	2.33 b[z]	2.99 c	2.91 c	3.96 c	4.20 c	5.94 d
Betula nigra	2.76 a	2.95 c	3.81 a	4.18 c	5.72 a	6.64 c
Pinus Elliotti	1.90 d	4.42 b	2.48 d	5.89 b	4.01 d	8.46 b
Quercus virginiana	2.07 c	2.65 d	2.96 c	3.76 c	3.88 d	5.59 d
Taxodium distichum	2.32 b	5.09 a	3.29 b	6.88 a	4.78 b	10.25 a
Application method, A						
Dibble	2.28	3.62	3.09	5.01	4.55	7.33
Topdress	2.27	3.61	3.09	4.86	4.49	7.42
Main effects						
Irrigation	NS	NS	NS	NS	NS	NS
Bag size	NS	NS	NS	NS	NS	NS
Species	**	**	**	**	**	**
Application method	NS	NS	NS	NS	NS	NS
Interactions						
SXBXI	NS	NS	NS	NS	NS	*
SXI	NS	NS	*	NS	**	**
AXS	NS	NS	NS	NS	*	*
AXB	*	*	NS	*	NS	**
AXI	NS	NS	NS	NS	NS	**

[z]Mean separation within main effects and columns by Duncan's multiple range test 5% level.

[**,*,NS]Significant at 1% and 5% levels and not significant, respectively.

Table 9. Interactions[z] of fertilizer application method and fabric bag on 1st year plant height and 1st, 2nd and 3rd year trunk caliper, *Expt. 3*.

		1st Year		2nd Year	3rd Year
Bag Size, B	Application method, A	Plant ht (m)	Trunk caliper (cm)	Trunk caliper (cm)	Trunk caliper (cm)
46-cm	dibble	2.348	3.76	5.25	7.60
46-cm	topdress	2.266	3.59	4.71	7.28
61-cm	dibble	2.216	3.49	4.77	7.07
61-cm	topdress	2.276	3.64	5.01	7.56
LSD (.05)[y]		NS	NS	.42	.42
LSD (.10)[y]		.076	.16	.35	.35
LSD (.05)[x]		.130	NS	.44	.52
LSD (.10)[x]		.107	.24	.37	.43

[z] Averaged over species and irrigation.
[y]Between A means for same B.
[x]Between B means for same or different A.

Table 10. Interaction[z] of fertilizer application method and irrigation on 3rd year plant height and trunk caliper, *Expt 3.*

Irrigation, I	Application method, A	Trunk caliper (cm)
Irrigated	dibble	7.14
Irrigated	topdress	7.64
Not irrigated	dibble	7.53
Not irrigated	topdress	7.20
LSD (.05)[y]		.42
LSD (.10)[y]		.35

[z]Averaged over species and bag size.
[y]Between A means for same I. Differences between I means for same or different A are not significant.

Table 11. Interactions[z] of fertilizer application method and species on 3rd year plant height and trunk caliper, *Expt. 3*.

Species, S	Application Method, A	Plant ht (m)	Trunk Caliper (cm)
Acer rubrum	Dibble	4.370	6. 38
	Topdress	4.037	5.50
Betula nigra	Dibble	5.742	6.58
	Topdress	5.688	6.70
Pinus Elliotti	Dibble	3.893	8.08
	Topdress	4.131	8.83
Quercus virginiana	Dibble	3.851	5.37
	Topdress	3.910	5.82
Taxodium distichum	Dibble	4.891	10.25
	Topdress	4.664	10.24
LSD (.05)[y]		.250	.67
LSD (.10)[y]		.210	.56
LSD (.05)[x]		.260	.67
LSD (.10)[x]		.218	.56

[z]Averaged over irrigation and bag size.
[y]Between A means for same S.
[x]Between S means for same or different A.

Table 12. Interactions[z] of irrigation and species on 2nd and 3rd year plant height, *Expt. 3.*

Species, S	Irrigation, I	2nd year plant ht.(m)	3rd year plant ht. (m)
Acer ruburm	Irrigated	2.813	3.993
	Not irrigated	3.003	4.415
Betula nigra	Irrigated	3.875	5.839
	Not irrigated	3.738	5.591
Pinus Elliotti	Irrigated	2.370	3.866
	Not irrigated	2.597	4.158
Quercus virginiana	Irrigated	3.063	4.016
	Not irrigated	2.850	3.746
Taxodium distichum	Irrigated	3.302	4.967
	Not irrigated	3.269	4.588
LSD (.05)[y]		.218	.270
LSD (.10)[y]		.182	.226
LSD (.05)[x]		.283	.298
LSD (.10)[x]		.230	.245

[z]Averaged over bag size and fertilizer application method
[y]Between S means for same I.
[x]Between I means for same or different S.

Table 13. Interaction[z] of species, bag size and irrigation for 3rd year trunk caliper (cm), *Expt. 3.*

Irrigation, I	Bag Size, B	*Acer rubrum*	*Betula nigra*	*Pinus Elliotti*	*Quercus virginiana*	*Taxodium distichum*
Irrigated	46-cm	6.14	6.82	7.79	5.41	11.04
Irrigated	61-cm	5.36	6.93	8.40	5.63	10.36
Not irrigated	46-cm	6.03	6.80	9.44	5.27	9.65
Not irrigated	61-cm	6.23	6.01	8.21	6.05	9.94
LSD (.05)[y]	1.05					
LSD (.10)[y]	.87					
LSD (.05)[x]	1.07					
LSD (.10)[x]	.88					

[z]Averaged over fertilizer application method.
[y]Between B means for same I and same or different species.
[x]Between I means for same or different B and species.

Table 14. The effect of irrigation and fabric bag size on root dry weights of 3-year-old harvested root balls of dibble fertilized *Acer rubrum* and *Pinus Elliotti, Expt. 3.*

Irrigation, I	Bag Size, B	*Acer rubrum*	*Pinus Elliotti*
Irrigated	46-cm	1993 ± 287[z]	1848 ± 1047
Irrigated	61-cm	1703 ± 755	1894 ± 984
Not irrigated	46-cm	2305 ± 316	3654 ± 1435
Not irrigated	61-cm	2660 ± 706	2399 ± 765
Significance[y]		I*	I*

[z]Values are means ± SD, n = 6.
[y]Significance by F test at 5% (*).

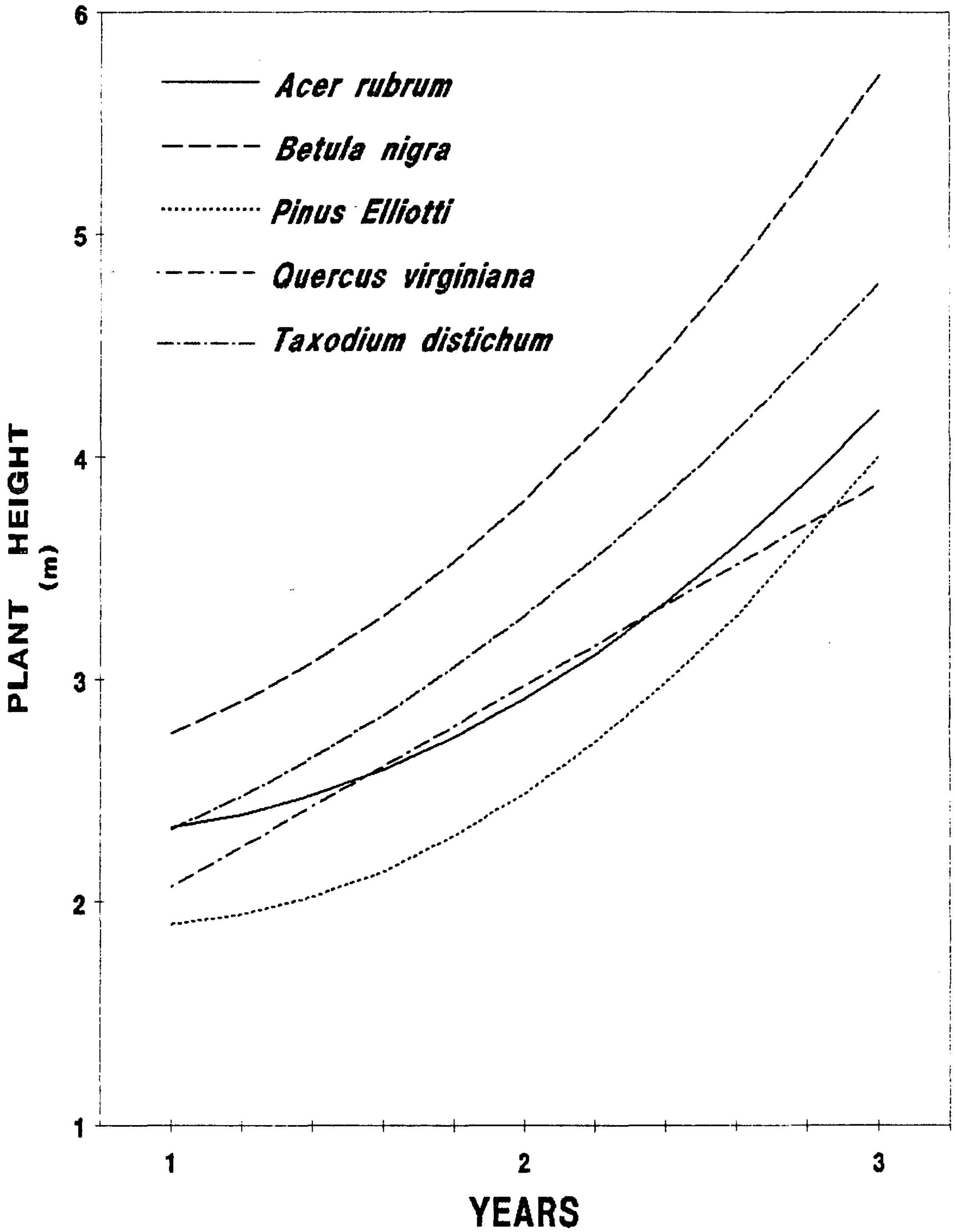

Fig 1. Relationship between time (years) and plant height (m) for five species grown in fabric field containers, *Expt. 3*. Regression equations for each species are: *Acer rubrum*, $y = 2.480 - .506979167 + .360520833x^2$, $r^2 = .77$; *Betula nigra*, $y = 2.561458333 - .2353125x + .428854167x^2$, $r^2 = .94$; *Pinus Elliotti*, $y = 2.259645833 - .832239583x + .472093750x^2$, $r^2 = .80$; *Quercus virginiana*, $y = 1.161041667 + .904322917x$, $r^2 = .81$; and *Taxodium distichum*, $y = 1.89375 + .165x + .265416667x^2$, $r^2 = .87$.

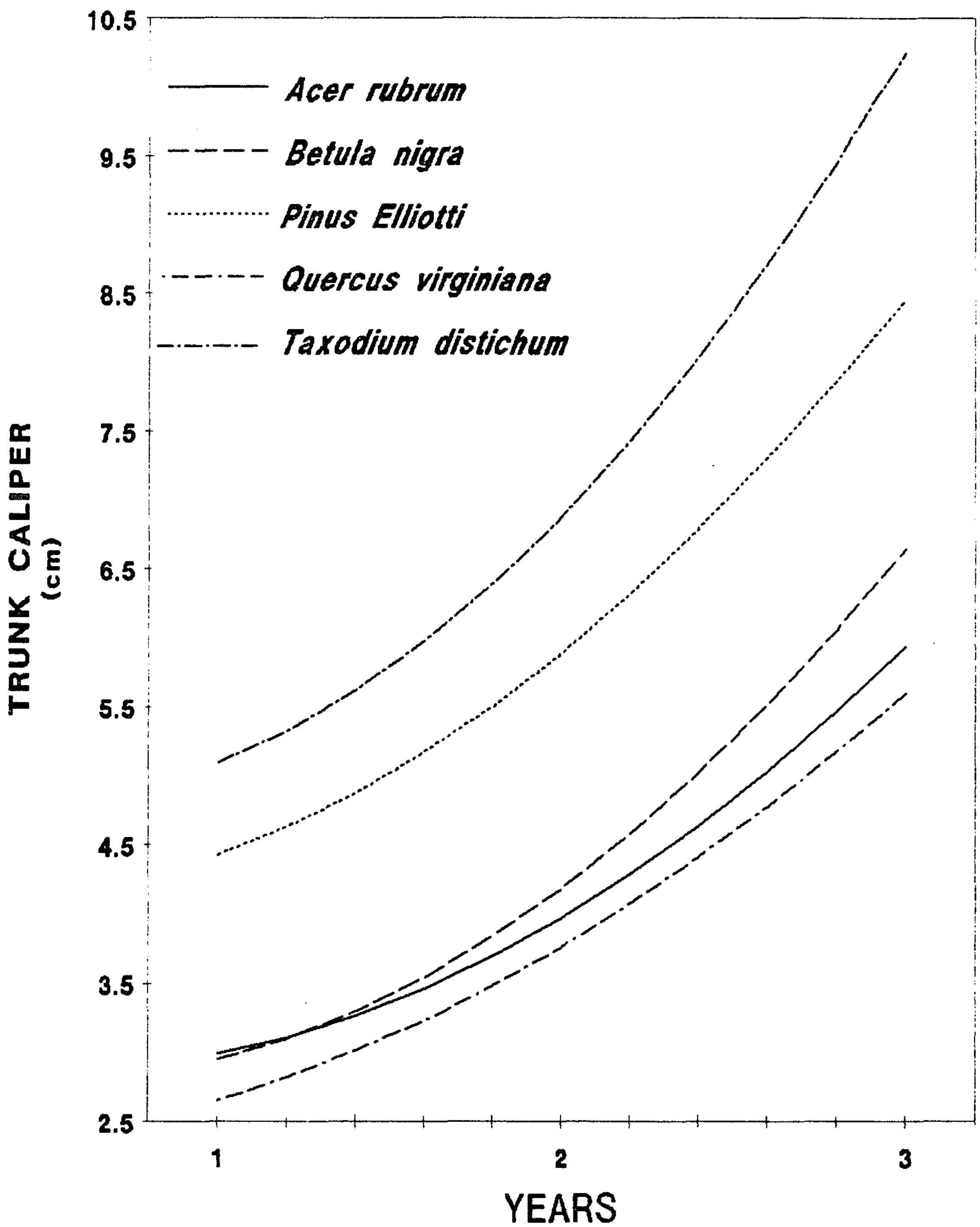

Fig. 2. Relationship between time (years) and trunk caliper (cm) for five species grown in fabric field containers, *Expt. 3.* Regression equations for each species are: *Acer rubrum*, $y = 3.009166667 - .520104167x + .498854167x^2$, $r^2 = .65$; *Betula nigra*, $y = 2.936979167 - .603107639x + .612586806x^2$, $r^2 = .88$; *Pinus Elliotti*, $y = 4.061458333 - .190104167x + .552187500x^2$, $r^2 = .67$; *Quercus virginiana*, $y = 2.25333 + .034895833x + .359270833x^2$, $r^2 = .81$; and *Taxodium distichum*, $y = 4.8845833 - .585520833x + .791145833x^2$, $r^2 = .62$.

Experiment 4. Six tree species were grown in 46-cm-diameter fabric bags, trickle irrigated and exposed to four rates of dibble applied slow release fertilizer. A positive response to increasing fertilizer rate was obtained only with *Acer* and *Taxodium* (Table 15). As N rate increased from 84 to 336 kg/ha there was a linear increase in 2nd year plant height for *Acer* and a curvilinear increase in 1st and 2nd year plant height for *Taxodium* with the greatest increase occurring at a N rate of 252 kg/ha (Fig 2). No significant trunk caliper differences due to N rates occurred for *Acer* and *Taxodium*.

Plant height and trunk caliper for *Liriodendron* decreased linearly with increasing N rates (Fig 1 and 2). N rates of 252 kg/ha and 336 kg/ha resulted in 37.5% and 62.5% mortality, respectively. Second year trunk caliper of *Quercus* also decreased linearly with increasing N rates (Fig 2). No significant plant height or trunk caliper differences due to N rates occurred for *Betula* and *Pinus* (Table 15). Tilt and Dickerson (120) and Ingram (56) have also reported no growth response to increasing fertilizer rates for fabric bag grown trees.

N rates greater than 84 kg/ha would not produce substantial or economic differences in plant growth for *Betula, Liriodendron,* and *Quercus.* Greatest trunk calipers were recorded for Acer and Pinus at N rates of 168 kg/ha and rates higher than this would be of no benefit. Taxodium growth was best at a N rate of 252 kg N/ha.

Table 15. Top growth response of six tree species to fertilizer rate, *Expt. 4*.

Rate Kg N/ha (lb N/A)	1st year plant ht. (m)	1st year trunk cal (cm)	2nd year plant ht. (m)	2nd year trunk cal (cm)
		Acer rubrum		
84 (75)	1.807	2.79	2.313	3.52
168 (150)	2.115	3.15	2.638	4.26
252 (225)	2.150	2.81	2.738	4.23
336 (300)	2.074	3.13	2.744	4.11
Significance	NS	NS	L*	NS
		Betula nigra		
84 (75)	2.716	2.63	3.721	3.63
168 (150)	2.754	2.74	3.694	3.84
252 (225)	2.704	2.79	3.669	3.81
336 (300)	2.608	2.47	3.686	3.63
Significance	NS	NS	NS	NS
		Liriodendron tulipifera[z]		
84 (75)	2.594	3.42	3.113	5.23
168 (150)	2.331	3.08	2.868	4.79
252 (225)	2.116	2.75	2.610	4.36
336 (300)	1.810	2.09	1.950	3.07
Significance	L**	L**	L*	L**
		Pinus Elliotti		
84 (75)	2.199	5.04	2.438	6.25
168 (150)	2.113	5.44	2.763	7.11
252 (225)	1.928	4.73	2.431	6.33
336 (300)	1.955	4.68	2.419	6.01
Significance	NS	NS	NS	NS
		Quercus virginiana		
84 (75)	1.985	2.93	2.994	4.35
168 (150)	1.996	2.72	2.950	4.15
252 (225)	1.916	2.52	2.750	4.03
336 (300)	1.885	2.58	2.931	3.73
Significance	NS	NS	NS	L*
		Taxodium distichum		
84 (75)	2.241	5.85	3.188	6.80
168 (150)	2.189	5.47	3.100	7.45
252 (225)	2.449	5.94	3.421	8.49
336 (300)	2.235	5.44	3.113	7.49
Significance	C*	NS	C*	NS

[z]Due to death n = 8, n = 8, n = 5, and n = 3 for rates of 84, 168, 252 and 336, respectively.

[NS,*,**] Not significant and significant at the .05 and .01 levels, respectively. L = linear and C = cubic.

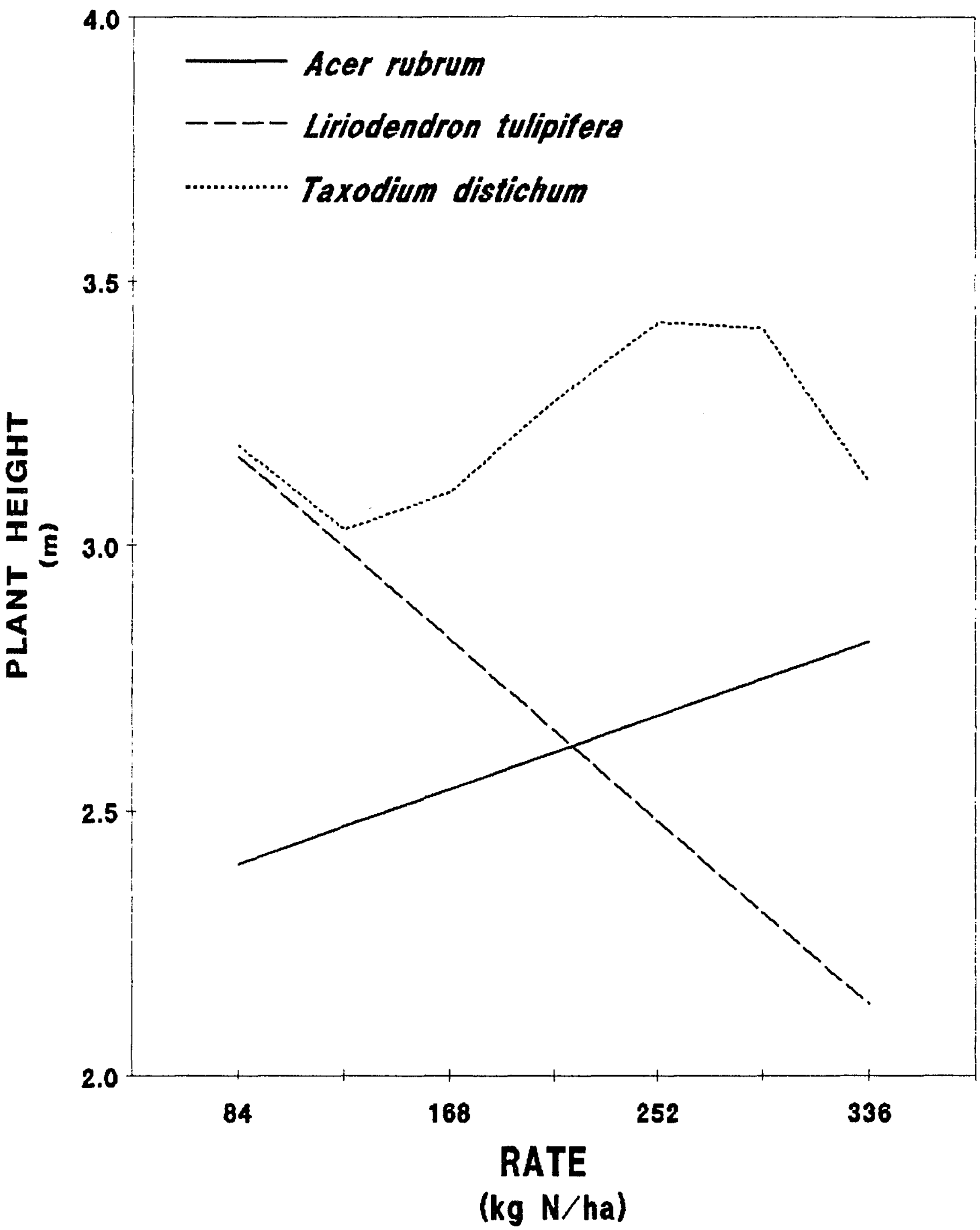

Fig. 3 Relationship between fertilizer rate and plant height for *Acer rubrum* ($y = 2.259375 + .001659226x$, $r^2 = .15$), *Lirioderdron tulipifera* ($y = 3.511591 - .004103215$, $r^2 = .23$), and *Taxodium distichum* ($y = 4.7225 - .031011905x + .00017618x^2 - .000000292x^3$, $r^2 = .19$), *Expt. 4*.

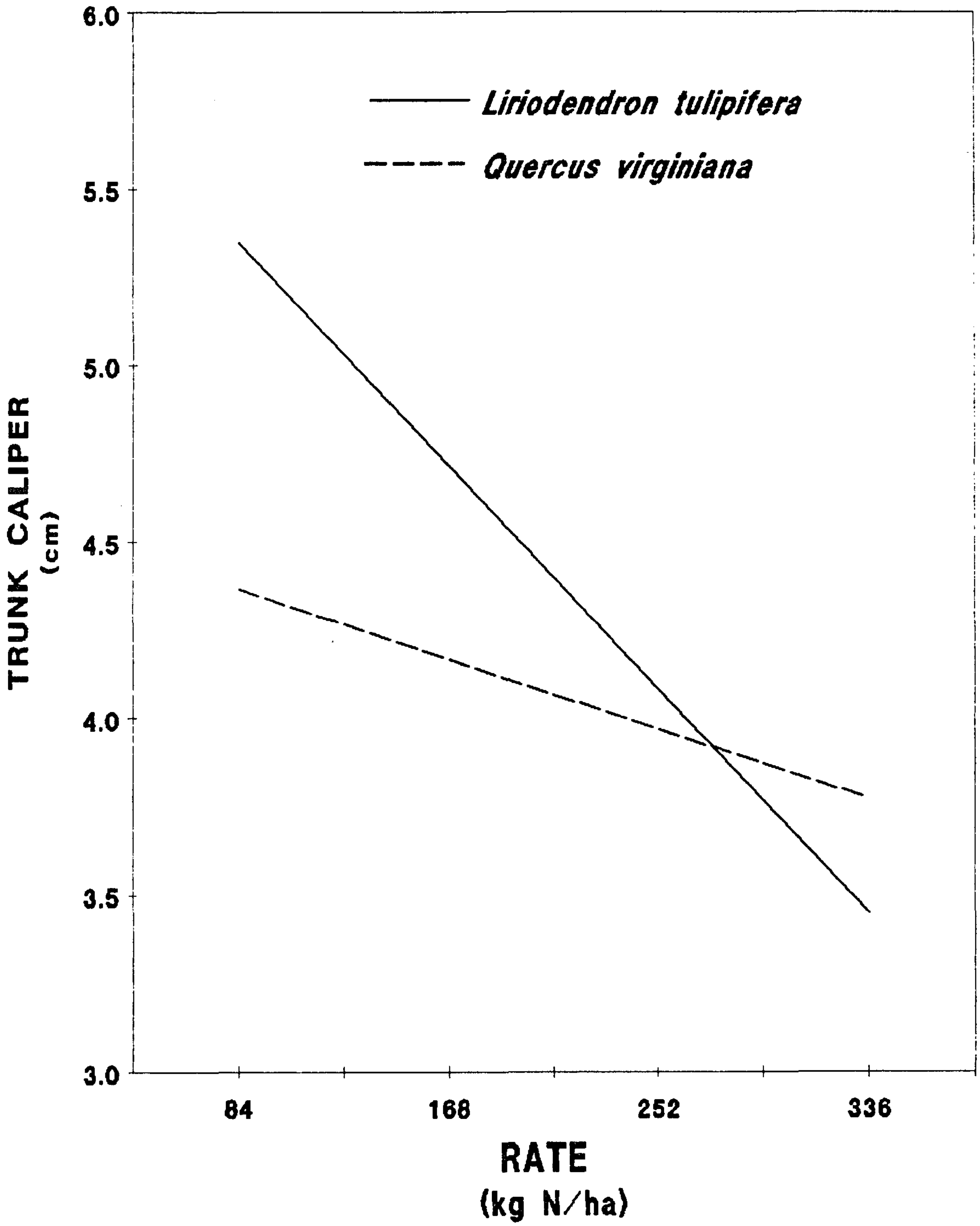

Fig 4. Relationship between fertilizer rate and trunk caliper for *Liriodendron tulipifera* (y = 5.97660 - .007522964, r^2 = .26) and *Quercus virginiana* (y = 4.563125 - .002364583x, r^2 = .12), *Expt. 4.*

Summary and Conclusions

Experiment 1.

Production methods (fabric bag, flat bed, and raised bed), irrigation and five tree species were evaluated for effects on top growth, root growth within the harvested root ball and root growth potential (RGP).

1) Planting method did not influence plant height or trunk caliper of *Acer, Pinus, Quercus* and *Taxodium*, whereas, *Betula* plant height was reduced by the fabric bag treatment.

2) Trickle irrigation had a positive impact on plant height, trunk caliper and root growth within the harvested root ball.

3) Fabric bags increased the number of fibrous roots and the root mass within the harvested root ball. Trees exhibited less leaf drop and wilt during the postharvest period, but survival differences between production methods were not observed.

4) A linear correlation between increased root mass within the harvested root ball of fabric bags and increased root growth potential (RGP) did not exist. Removal of the fabric bag damaged roots on the surface of those root balls remaining intact.

5) Root balls of *Acer* and *Quercus* grown in fabric bags were especially sensitive to postharvest handling. B & B nursery stock

was protected by wire baskets and withstood more abuse than fabric bags. These observations could have implications on transport and stacking of fabric bag nursery stock.

Experiment 2.

Four fertilizer sources and trickle irrigation were evaluated for effects on top growth of five tree species grown in 46-cm-diameter fabric bags.

1) Trickle irrigation had a positive impact on top growth for all five species grown in 46-cm-diameter fabric bags.

2) Fertilizer source had no effect on plant height or trunk caliper for the first or second year of tree growth.

3) *Taxodium* produced the largest trunk caliper after one and two years, followed in ranking by *Pinus.*

Experiment 3.

Fertilizer application method (top-dress and dibble), fabric bag size (46-cm and 61-cm) and trickle nirrigation were evaluated for effects on top growth and root growth within the harvested root ball of five tree species.

1) Dibble applied Osmocote produced better growth of trees in 46-cm-diameter fabric bags whereas top-dressed Osmocote

produced better growth of trees in 61-cm-diameter fabric bags (averaged over all species and irrigation levels).

2) Excessive leaching with irrigated treatments may have been responsible for reducing nutrients levels below optimum for dibble applied fertilizer treatments and a corresponding reduction in 3rd year trunk caliper.

3) Species responded differently from each other to fertilizer application method during the 3rd year of growth. *Acer* benefitted from dibble application and Pinus from top-dressed application.

4) *Betula*, *Quercus* and *Taxodium* responded in a positive manner to trickle irrigation. Top growth and harvested root systems of *Acer* and *Pinus* were negatively affected by trickle irrigation.

5) Predicted lengths of time to reach 5.1-cm-diameter trunk caliper for fabric bag grown trees were approximately 1.50, 1.75, 2.50, 2.75 and 3.00 years for *Taxodium, Pinus, Betula, Acer* and *Quercus*, respectively. Implications of these data are of a practical nature to the nursery industry since it is extremely difficult to coordinate optimal harvesting time based on trunk caliper and soil volume to the peak sales period and a retail customer's needs. B & B plants offer more versatility and allow harvesting of various trunk caliper and root volumes.

Experiment 4.

Top growth response of six tree species to slow release fertilizer rate in fabric bags.

1) N rates greater than 84 kg/ha were not beneficial to top growth (plant height and trunk caliper) for *Betula, Liriodendron* and *Quercus*.

2) *Acer* and *Pinus* did not benefit from N rates higher than 168 kg/ha.

3) *Taxodium* produced best growth at a N rate of 252 kg/ha.

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APPENDIX

Table 16. Analysis of variance of plant height (m) for 1st year, *Expt. 1.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	4	0.6235706	2.53	.1952
Irrigation, I	1	1.7484914	28.39	.0060**
Error (a)	4	0.2463416		
Planting Method, P	2	0.5879178	1.89	.1827
PXI	2	0.3937485	1.27	.3080
Error (b)	16	2.4830036		
Species, S	4	9.8530890	22.45	.0001**
SXI	4	0.2834410	0.65	.6311
SXP	8	1.5075780	1.72	.1040
SXPXI	8	0.7502142	0.85	.5574
Error (c)	96	10.5322234		
Sampling Error (s)	150	12.0776045		
Total	299	41.0872235		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 11.2%; CV (b) = 17.7%; CV (c) = 14.9%; CV (s) = 12.8%.

Experimental mean = 2.220 m.

Table 17. Analysis of variance of plant height (m) for 2nd year, *Expt. 1*.

Source	df	Sums of squares	F value	Pr > F^{z}
Block	4	2.3554567	6.88	.0442*
Irrigation, I	1	3.4580656	40.41	.0031**
Error (a)	4	0.3422626		
Planting Method, P	2	0.5460471	0.75	.4898
PXI	2	0.2107871	0.29	.7534
Error (b)	16	5.8515278		
Species, S	4	16.4892899	21.27	.0001**
SXI	4	0.2535972	0.33	.8592
SXP	8	4.0193620	2.59	.0131*
SXPXI	8	1.4964979	0.97	.4680
Error (c)	96	18.6090725		
Sampling Error (s)	150	22.2003775		
Total	299	75.8323440		

^{z}Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 9.5%; CV (b) = 19.6%; CV (c) = 14.3%; CV (s) = 12.5%.

Experimental mean = 3.085 m.

Table 18. Analysis of variance of trunk caliper (cm) for 1st year, *Expt. 1.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	4	1.21797	1.36	.3854
Irrigation, I	1	5.26953	23.61	.0083**
Error (a)	4	0.89275		
Planting Method, P	2	2.15462	1.33	.2918
PXI	2	1.20976	0.75	.4893
Error (b)	16	12.94446		
Species, S	4	182.74557	107.07	.0001**
SXI	4	1.82962	1.07	.3747
SXP	8	4.80598	1.41	.2030
SXPXI	8	1.88263	0.55	.8147
Error (c)	96	40.96266		
Sampling Error (s)	150	48.37220		
Total	299	304.28775		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 13.5%; CV (b) = 25.7%; CV (c) = 18.7%; CV (s) = 16.2.

Experimental mean = 3.50 cm.

Table 19. Analysis of variance of trunk caliper (cm) for 2nd year, *Expt 1.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	4	2.23524	3.61	.1205
Irrigation, I	1	9.39516	60.77	.0015**
Error (a)	4	0.61844		
Planting Method, P	2	0.01715	0.00	.9958
PXI	2	4.13720	1.02	.3836
Error (b)	16	32.51375		
Species, S	4	618.87747	191.80	.0001**
SXI	4	5.67240	1.76	.1437
SXP	8	8.49851	1.32	.2444
SXPXI	8	4.38767	0.68	.7081
Error (c)	96	77.44031		
Sampling Error(s)	150	86.19875		
Total	299	849.99920		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 7.8%; CV (b) = 28.2%, CV (c) = 17.7%; CV (s) = 15.0%.

Experimental mean = 5.06 cm.

Table 20. Analysis of variance of root dry weight (g) for two year harvested root ball, *Expt. 1.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	4	1783906.24	0.98	.5085
Irrigation, I	1	5778090.67	12.66	.0236*
Error (a)	4	1825025.87		
Planting Method, P	2	12418123.00	15.73	.0002**
PXI	2	2059264.25	2.61	.1046
Error (b)	16	6316002.61		
Species, S	4	46937837.44	39.50	.0001**
SXI	4	1260530.40	1.06	.3803
SXP	8	5503073.20	2.32	.0257*
SXPXI	8	1482376.88	0.62	.7560
Error (c)	96	28519727.68		
Total	149	113883958.24		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 41.9%, CV (b) = 39.0%; CV (c) = 33.8%.

Experimental mean = 1610.7 g.

Table 21. Analysis of variance of root mass density (g · liter $^{-1}$) for two year harvested root ball, *Expt.1*

Source	df	Sums of squares	F value	Pr > F[z]
Block	4	470.2047	0.83	.5695
Irrigation, I	1	1707.0248	12.05	.0256*
Error (a)	4	566.6075		
Planting Method, P	2	8396.6769	34.49	.0001**
PXI	2	751.1664	3.09	.0736
Error (b)	16	1947.8782		
Species, S	4	12740.5697	36.39	.0001**
SXI	4	378.2467	1.08	.3706
SXP	8	1798.4573	2.57	.0139*
SXPXI	8	461.2817	0.66	.7262
Error (c)	96	8401.6458		
Total	149	37619.7597		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 44.2%; CV (b) = 41.0%; CV (c) = 34.8%.

Experimental mean = 26.9 g · liter^{-1}.

Table 22. Analysis of variance of root rating[z] for two year harvested root ball of, *Expt. 1.*

Source	df	Sums of squares	F value	Pr > F[y]
Block	4	3.0933	1.57	.3369
Irrigation, I	1	50.4600	102.28	.0005**
Error (a)	4	1.9733		
Planting Method, P	2	300.8533	304.92	.0001**
PXI	2	1.1200	1.14	.3459
Error (b)	16	7.8933		
Species, S	4	22.2267	12.28	.0001**
SXI	4	2.4400	1.35	.2578
SXP	8	4.4133	1.22	.2962
SXPXI	8	7.0800	1.96	.0604
Error (c)	96	43.4400		
Total	149	444.9933		

[z]Based on scale of 1-10 (1 = lowest fibrous and total root mass, 10 = highest fibrous and total root mass)

[y]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 12.3%; CV (b) = 12.3%; CV (c) = 11.9%.

Experimental mean = 5.7.

Table 23. Analysis of variance of root growth potential [root dry weight (g)], *Expt. 1*.

Source	df	Sums of squares	F value	Pr > F[z]
Block	4	1908.693	4.99	.0743
Irrigation, I	1	486.000	5.08	.0872
Error (a)	4	382.400		
Planting Method, P	2	492.160	0.92	.4173
PXI	2	511.840	0.96	.4037
Error (b)	16	4263.467		
Species, S	4	75683.960	91.17	.0001**
SXI	4	362.200	0.44	.7821
SXP	8	9517.840	5.73	.0001**
SXPXI	8	1861.360	1.12	.3561
Error (c)	96	19922.640		
Total	149	115392.560		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 27.6%; CV (b) = 46.1%; CV (c) = 40.7%.

Experimental mean = 35.4 g.

Table 24. Analysis of variance of plant height (m) for 1st year, *Expt. 2.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	5	0.1858171	0.49	.7759
Irrigation, I	1	0.6070204	7.95	.0371*
Error (a)	5	0.3817471		
Species, S	4	10.6519025	22.46	.0001**
SXI	4	0.3859275	0.81	.5240
Error (b)	40	4.7427900		
Fertilizer, F	3	0.0759746	0.33	.8035
FXS	12	0.4423942	0.60	.6159
FXI	3	0.1380479	0.48	.9236
FXSXI	12	1.0180625	1.11	.3590
Error (c)	150	11.5023958		
Total	239	30.1320796		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 12.1% ; CV (b) = 15.1% ; CV (c) = 12.1% .

Experimental mean = 2.283 m.

Table 25. Analysis of variance of plant height (m) for 2nd year, *Expt. 2.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	5	0.4650833	1.60	.3095
Irrigation, I	1	1.0140000	17.42	.0087**
Error (a)	5	0.2908750		
Species, S	4	42.5937083	51.82	.0001**
SXI	4	1.4349583	1.75	.1590
Error (b)	40	8.2188333		
Fertilizer, F	3	0.0402083	0.14	.9370
FXS	12	1.2577083	0.48	.6979
FXI	3	0.1390833	1.08	.3800
FXSXI	12	1.7927917	1.54	.1154
Error (c)	150	14.5427083		
Total	239	71.78995833		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 7.7%; CV (b) = 14.5% ; CV (c) = 10.0% .

Experimental mean = 3.117 m.

Table 26. Analysis of variance of trunk caliper (cm) for 1st year, *Expt. 2.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	5	1.92256	3.11	.1191
Irrigation, I	1	2.00264	16.22	.0100**
Error (a)	5	0.61742		
Species, S	4	203.57233	179.47	.0001**
SXI	4	1.46472	1.29	.2897
Error (b)	40	11.34313		
Fertilizer, F	3	0.71673	0.91	.4356
FXS	12	2.69411	1.43	.2373
FXI	3	1.11831	0.86	.5897
FXSXI	12	2.92125	0.93	.5172
Error (c)	150	39.19636		
Total	239	267.56955		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 9.8%; CV (b) = 14.8% ; CV (c) = 14.2% .

Experimental mean = 3.60 cm.

Table 27. Analysis of variance of trunk caliper (cm) for 2nd year, *Expt. 2.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	5	3.46571	0.59	.7135
Irrigation, I	1	7.53903	6.39	.0527
Error (a)	5	5.90358		
Species, S	4	449.98004	219.19	.0001**
SXI	4	1.12191	0.55	.7026
Error (b)	40	20.52932		
Fertilizer, F	3	0.78509	0.33	.8024
FXS	12	6.66737	1.13	.3400
FXI	3	2.66787	0.70	.7456
FXSXI	12	16.70162	1.76	.0590
Error (c)	150	118.33787		
Total	239	633.69942		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 21.7% ; CV (b) = 14.3% ; CV (c) = 17.7%.

Experimental mean = 5.01 cm.

Table 28. Analysis of variance of plant height (m) for 1st year, *Expt. 3.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	5	0.8083571	0.64	.6795
Irrigation, I	1	0.0066782	0.03	.8768
Error (a)	5	1.2549577		
Bag Size, B	1	0.2216768	1.42	.2613
BXI	1	0.1423988	0.91	.3625
Error (b)	10	1.5638702		
Species, S	4	20.0833269	54.48	.0001**
SXI	4	0.9086893	2.46	.0516
SXB	4	0.2227639	0.60	.6607
SXBXI	4	0.5073069	1.38	.2496
Error (c)	80	7.3727433		
Application Method, A	1	0.0071068	0.11	.7369
AXS	4	0.5205539	2.08	.0893
AXI	1	0.0291721	0.47	.4965
AXB	1	0.3077368	4.91	.0289*
AXIXS	4	0.1126236	0.45	.7725
AXBXI	1	0.0093002	0.75	.5621
AXBXS	4	0.1871723	0.15	.7008
AXBXIXS	4	0.5060973	2.02	.0973
Error (d)	100	6.2623750		
Total	239	41.0349072		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 22.0%; CV (b) = 17.4%; CV (c) = 13.3%; CV (d) = 11.0%.

Experimental mean = 2.277 m.

Table 29. Analysis of variance of plant height (m) for 2nd year, *Expt. 3.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	5	0.8380533	0.42	.8179
Irrigation, I	1	0.0029400	0.01	.9349
Error (a)	5	1.9904450		
Bag Size, B	1	0.1949400	0.56	.4728
BXI	1	0.0025350	0.01	.9339
Error (b)	10	3.5016050		
Species, S	4	46.5570875	80.86	.0001**
SXI	4	1.8368642	3.19	.0175*
SXB	4	0.6891142	1.20	.3187
SXBXI	4	0.6812608	1.18	.3245
Error (c)	80	11.5149133		
Application Method, A	1	0.0013067	0.02	.9000
AXS	4	0.5419975	1.65	.1688
AXI	1	0.2100417	2.55	.1134
AXB	1	0.0534017	0.65	.4226
AXIXS	4	0.2097542	0.64	.6375
AXBXI	1	0.0129067	1.07	.3744
AXBXS	4	0.3532275	0.16	.6931
AXBXIXS	4	0.5229808	1.59	.1835
Error (d)	100	8.2361833		
Total	239	77.951558333		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 20.4% ; CV (b) = 19.2% ; CV (c) = 12.3% ; CV (d) = 9.3%.

Experimental mean = 3.088 m.

Table 30. Analysis of variance of plant height (m) for 3rd year, *Expt. 3.*

Source	df	Sums of squares	F value	Pr > F^z
Block	5	2.4117671	1.68	.2906
Irrigation, I	1	0.0795704	0.28	.6207
Error a	5	1.4320471		
Bag Size, B	1	0.1831537	0.63	.4471
BXI	1	0.0847504	0.29	.6022
Error (b)	10	2.9252108		
Species, S	4	108.5655827	122.57	.0001**
SXI	4	6.4105160	7.24	.0001**
SXB	4	0.7486744	0.85	.5006
SXBXI	4	1.7620694	1.99	.1040
Error (c)	80	17.7141625		
Application Method, A	1	0.2413004	1.26	.2641
AXS	4	2.4705235	3.23	.0155*
AXI	1	0.4977704	2.60	.1099
AXB	1	0.0000938	0.00	.9824
AXIXS	4	0.7185785	0.94	.4448
AXBXI	1	0.0717600	1.24	.2984
AXBXS	4	0.9499385	0.38	.5417
AXBXIXS	4	1.1195385	1.46	.2192
Error (d)	100	19.1343708		
Total	239	167.5213796		

^{z}Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 11.8%; CV (b) = 12.0%; CV (c) = 10.4% ; CV (d) = 9.7% .

Experimental mean = 4.518 m.

Table 31. Analysis of variance of trunk caliper (cm) for 1st year, *Expt. 3.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	5	2.64737	0.94	.5266
Irrigation, I	1	0.14357	0.25	.6353
Error (a)	5	2.81893		
Bag Size, B	1	0.74854	0.88	.3690
BXI	1	0.16520	0.20	.6680
Error (b)	10	8.45957		
Species, S	4	221.09433	110.65	.0001**
SXI	4	4.95650	2.48	.0504
SXB	4	0.69499	0.35	.8448
SXBXI	4	1.93067	0.97	.4307
Error (c)	80	39.96283		
Application Method, A	1	0.00551	0.02	.8907
AXS	4	2.42427	2.09	.0881
AXI	1	0.29704	1.02	.3143
AXB	1	1.51951	5.23	.0243*
AXIXS	4	0.13049	0.11	.9779
AXBXI	1	0.33227	0.60	.6601
AXBXS	4	0.70258	1.14	.2874
AXBXIXS	4	1.69654	1.46	.2200
Error (d)	100	29.04350		
Total	239	319.77421		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 20.7%; CV (b) = 25.4%; CV (c) = 19.5%; CV (d) = 14.9%.

Experimental mean = 3.62 cm.

Table 32. Analysis of variance of trunk caliper (cm) for 2nd year, *Expt. 3.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	5	17.07631	6.68	.0287*
Irrigation, I	1	0.17191	0.34	.5872
Error (a)	5	2.55646		
Bag Size, B	1	0.58050	0.44	.5226
BXI	1	0.28176	0.21	.6543
Error (b)	10	13.22640		
Species, S	4	363.76110	62.72	.0001**
SXI	4	10.05967	1.73	.1506
SXB	4	0.86177	0.15	.9631
SXBXI	4	6.77821	1.17	.3309
Error (c)	80	116.00095		
Application Method, A	1	1.36052	1.00	.3208
AXS	4	6.89171	1.26	.2905
AXI	1	0.43095	0.32	.5757
AXB	1	9.14031	6.69	.0111*
AXIXS	4	2.93336	0.54	.7092
AXBXI	1	0.28589	1.43	.2294
AXBXS	4	7.81979	0.21	.6484
AXBXIXS	4	0.43946	0.08	.9882
Error (d)	100	136.66547		
Total	239	697.32250		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 14.5% ; CV (b) = 23.3%; CV (c) = 24.4%; CV (d) = 23.7%.

Experimental mean = 4.93 cm.

Table 33. Analysis of variance of trunk caliper (cm) for 3rd year, *Expt. 3.*

Source	df	Sums of squares	F value	Pr > F[z]
Block	5	9.65788	0.89	.5504
Irrigation, I	1	0.03094	0.01	.9097
Error (a)	5	10.87926		
Bag Size, B	1	0.97857	0.43	.5284
BXI	1	0.02937	0.01	.9122
Error (b)	10	22.94128		
Species, S	4	730.48101	131.24	.0001**
SXI	4	20.75604	3.73	.0078**
SXB	4	6.07551	1.09	.3665
SXBXI	4	19.26700	3.46	.0116*
Error (c)	80	111.31899		
Application Method, A	1	0.45632	0.33	.5655
AXS	4	18.26587	3.33	.0133*
AXI	1	10.21144	7.44	.0075**
AXB	1	9.87190	7.19	.0086**
AXIXS	4	4.26001	0.78	.5435
AXBXI	1	1.40072	0.83	.5088
AXBXS	4	4.56053	1.02	.3148
AXBXIXS	4	9.15325	1.67	.1636
Error (d)	100	137.26412		
Total	239	1127.85998		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability, CV: CV (a) = 20.0%; CV (b) = 20.5%; CV (c) = 16.0%; CV (d) = 15.9%.

Experimental mean = 7.38 cm.

Table 34. Regression analysis of the relationship between time (years 1,2&3) and plant height and trunk caliper for *Acer rubrum*, *Expt. 3*.

Source	df	Sums of squares	r^2	F value	Pr > F[z]
		Plant height (m)[y]			
Total	143	114.593464			
Linear component	**1**	**83.944301**	**.73**	**388.92**	**.0001****
Deviations from linear	142	30.649163			
Quadratic component	**1**	**4.159208**	**.77**	**22.14**	**.0001****
Deviations from quadratic	141	26.489955			
		Trunk caliper (cm)[x]			
Total	143	331.37706			
Linear component	**1**	**208.94851**	**.63**	**242.40**	**.0001****
Deviations from linear	142	122.42855			
Quadratic component	**1**	**7.96338**	**.65**	**9.81**	**.0021****
Deviations from quadratic	141	114.46517			

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

[y]The quadratic regression equation is $y = 2.480 - .506979167x + .360520833x^2$; Coefficient of variability = 13.8%; and Experimental mean = 3.148 m.

[x]The quadratic regression equation is $y = 3.009166667 - .520104167x + .498854167x^2$; Coefficient of variability = 21.0%; and Experimental mean = 4.30 cm.

Table 35. Regression analysis of the relationship between time (years 1,2&3) and plant height and trunk caliper for *Betula nigra*, *Expt. 3.*

Source	df	Sums of squares	r^2	F value	Pr > F^z
		Plant height (m)^y			
Total	143	230.634633			
Linear component	**1**	**210.308001**	**.91**	**1469.19**	**.0001****
Deviations from linear	142	20.326632			
Quadratic component	**1**	**5.885309**	**.94**	**57.46**	**.0001****
Deviations from quadratic	141	14.441323			
		Trunk caliper (cm)^x			
Total	143	388.06614			
Linear component	**1**	**327.58023**	**.84**	**769.05**	**.0001****
Deviations from linear	142	60.48591			
Quadratic component	**1**	**12.00840**	**.88**	**34.93**	**.0001****
Deviations from quadratic	141	48.47751			

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

[y]The quadratic regression equation is $y = 2.561458333 - .2353125x + .428854167x^2$; Coefficient of variability = 7.8%; and Experimental mean = 4.092 m.

[x]The quadratic regression equation is $y = 2.936979167 - .603107639x + .612586806x^2$; Coefficient of variability = 12.8%; and Experimental mean = 4.59 cm.

Table 36. Regression analysis of the relationship between time (years 1,2&3) and plant height and trunk caliper for *Pinus Elliotti, Expt.3*

Source	df	Sums of squares	r^2	F value	Pr > F^z
		Plant height (m)[y]			
Total	143	143.404730			
Linear component	**1**	**107.080514**	**.75**	**418.60**	**.0001****
Deviations from linear	142	36.324216			
Quadratic component	**1**	**7.131920**	**.80**	**34.45**	**.0001****
Deviations from quadratic	141	29.192296			
		Trunk caliper (cm)[x]			
Total	143	600.88399			
Linear component	**1**	**391.19338**	**.65**	**264.91**	**.0001****
Deviations from linear	142	209.69061			
Quadratic component	**1**	**9.75715**	**.67**	**6.88**	**.0001****
Deviations from quadratic	141	199.93346			

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

[y]The quadratic regression equation is $y = 2.259645833 - .832239583x + .472093750x^2$; Coefficient of variability = 16.3%; and Experimental mean = 2.798 m.

[x]The quadratic regression equation is $y = 4.061458333 - .190104167x + .552187500x^2$; Coefficient of variability = 19.0%; and Experimental mean = 6.26 cm.

Table 37. Regression analysis of the relationship between time (years 1,2&3) and plant height and trunk caliper for *Quercus virginiana*, *Expt. 3*.

Source	df	Sums of squares	r^2	F value	Pr > F[z]
		Plant height (m)[y]			
Total	143	97.219810			
Linear component	**1**	**78.508793**	**.81**	**595.81**	**.0001****
Deviations from linear	142	18.711017			
Quadratic component	**1**	**0.013001**	**.81**	**0.10**	**.7547**
Deviations from quadratic	141	18.698016			
		Trunk caliper (cm)[x]			
Total	143	262.23059			
Linear component	**1**	**208.00538**	**.79**	**544.71**	**.0001****
Deviations from linear	142	54.22521			
Quadratic component	**1**	**4.13041**	**.81**	**11.63**	**.0008****
Deviations from quadratic	141	50.09480			

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

[y]The linear regression equation is $y = 1.161041667 + .904322917x$; Coefficient of variability = 12.2%; and Experimental mean = 2.970 m.

[x]The quadratic regression equation is $y = 2.25333 + .034895833x + .359270833x^2$; Coefficient of variability = 14.9%; and Experimental mean = 4.00 cm.

Table 38. Regression analysis of the relationship between time (years 1,2&3) and plant height and trunk caliper for *Taxodium distichum*, *Expt. 3.*

Source	df	Sums of squares	r^2	F value	Pr > F[z]
		Plant height (m)[y]			
Total	143	169.186797			
Linear component	**1**	**144.452267**	**.85**	**829.29**	**.0001****
Deviations from linear	142	24.734530			
Quadratic component	**1**	**2.254272**	**.87**	**14.14**	**.0002****
Deviations from quadratic	141	22.480258			
		Trunk caliper (cm)x			
Total	143	1075.22855			
Linear component	**1**	**638.55008**	**.59**	**207.65**	**.0001****
Deviations from linear	142	436.67847			
Quadratic component	**1**	**20.02917**	**.62**	**6.78**	**.0102***
Deviations from quadratic	141	416.64930			

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

[y]The quadratic regression equation is $y = 1.89375 + .165x + .265416667x^2$; Coefficient of variability = 11.5%; and Experimental mean = 3.462 m.

[x]The quadratic regression equation is $y = 4.8845833 - .585520833x + .791145833x^2$; Coefficient of variability = 23.2%; and Experimental mean = 7.41 cm.

Table 39. Regression analysis of the relationship between fertilizer rate (kg N/ha) and 1st and 2nd year plant height for *Acer rubrum*, *Expt. 4*.

Source	df	Sums of squares	F value	Pr > F[z]
		1st Year Plant Height (m)		
Total	31	3.146888		
Linear component	**1**	**0.275560**	**2.88**	**.1001**
Deviations from linear	30	2.871328		
Quadratic component	**1**	**0.292613**	**3.29**	**.0800**
Deviations from quadratic	29	2.578715		
Cubic component	**1**	**0.010240**	**0.11**	**.7408**
Deviations from cubic	28	2.568475		
		2nd Year Plant Height (m)		
Total	31	5.090548		
Linear component[y]	**1**	**0.777016**	**5.40**	**.0270***
Deviations from linear	30	4.313532		
Quadratic component	**1**	**0.203203**	**1.43**	**.2409**
Deviations from quadratic	29	4.110329		
Cubic component	**1**	**0.006891**	**0.05**	**.8299**
Deviations from cubic	28	4.103438		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

[y]The linear regression equation is $y = 2.259375 + .001659226x$, $r^2 = .15$.

Coefficient of variability = 14.9% and 14.7% for 1st and 2nd year, respectively (estimated with error term of cubic model).

Experimental mean = 2.037 m and 2.608 m for 1st and 2nd year, respectively.

Table 40. Regression analysis of the relationship between fertilizer rate (kg N/ha) and 1st and 2nd year plant height for *Betula nigra*, *Expt. 4*.

Source	df	Sums of squares	F value	Pr > F[z]
		1st Year Plant Height (m)		
Total	31	1.070122		
Linear component	**1**	**0.010080**	**0.29**	**.5972**
Deviations from linear	30	1.060042		
Quadratic component	**1**	**0.007503**	**0.21**	**.6527**
Deviations from quadratic	29	1.052539		
Cubic component	**1**	**0.005176**	**0.14**	**.7127**
Deviations from cubic	28	1.047363		
		2nd Year Plant Height (m)		
Total	31	2.339535		
Linear component	**1**	**0.002426**	**0.03**	**.8611**
Deviations from linear	30	2.337109		
Quadratic component	**1**	**0.007844**	**0.10**	**.7569**
Deviations from quadratic	29	2.329265		
Cubic component	**1**	**0.001317**	**0.02**	**.9008**
Deviations from cubic	28	2.327948		

[z]Probability (Pr) of a greater F va lue. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability = 7.1% and 7.8% for 1st and 2nd year, respectively (estimated with error term of cubic model).

Experimental mean = 2.713 m and 3.697 m for 1st and 2nd year, respectively.

Table 41. Regression analysis of the relationship between fertilizer rate (kg N/ha) and 1st and 2nd year plant height for *Lirodendron tulipfera*, *Expt. 4.*

Source	df	Sums of squares	F value	Pr > F[z]
		1st Year Plant Height (m)		
Total	23	5.295663		
Linear component[y]	**1**	**1.579323**	**9.35**	**.0058****
Deviations from linear	22	3.716340		
Quadratic component	**1**	**0.000916**	**0.01**	**.9433**
Deviations from quadratic	21	3.715424		
Cubic component	**1**	**0.005629**	**0.03**	**.8635**
Deviations from cubic	20	3.709795		
		2nd Year Plant Height (m)		
Total	23	12.679583		
Linear component[x]	**1**	**2.925387**	**6.60**	**.0175***
Deviations from linear	22	9.754196		
Quadratic component	**1**	**0.176216**	**0.39**	**.5409**
Deviations from quadratic	21	9.577980		
Cubic component	**1**	**0.048480**	**0.10**	**.7530**
Deviations from cubic	20	9.529500		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

[y]The linear regression equation is $y = 2.846904 - .003014866x$, $r^2 = .30$.

[x]The linear regression equation is $y = 3.511591 - .004103215x$, $r^2 = .23$.

Coefficient of variability = 18.7% and 24.8% for 1st and 2nd year, respectively (estimated with error term of cubic model).

Experimental mean = 2.309 m and 2.779 m for 1st and 2nd year, respectively.

Table 42. Regression analysis of the relationship between fertilizer rate (kg N/ha) and 1st and 2nd year plant height for *Pinus Elliotti*, *Expt. 4.*

Source	df	Sums of squares	F value	Pr > F^z
		1st Year Plant Height (m)		
Total	31	7.488621		
Linear component	**1**	**0.335805**	**1.41**	**.2446**
Deviations from linear	30	7.152816		
Quadratic component	**1**	**0.025877**	**.11**	**.7479**
Deviations from quadratic	29	7.126939		
Cubic component	**1**	**0.038751**	**0.15**	**.6986**
Deviations from cubic	28	7.088188		
		2nd Year Plant Height (m)		
Total	31	6.585000		
Linear component	**1**	**0.060062**	**0.28**	**.6031**
Deviations from linear	30	6.524938		
Quadratic component	**1**	**0.227813**	**1.05**	**.3142**
Deviations from quadratic	29	6.297125		
Cubic component	**1**	**0.380250**	**1.80**	**.1906**
Deviations from cubic	28	5.916875		

[z]Probabality (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability = 24.6% and 18.3% for 1st and 2nd year, respectively (estimated with error term of cubic model).

Experimental mean = 2.048 m and 2.513 m for 1st and 2nd year, respectively.

Table 43. Regression analysis of the relationship between fertilizer rate (kg N/ha) and 1st and 2nd year plant height for *Quercus virginiana*, *Expt. 4.*

Source	df	Sums of squares	F value	Pr > F[z]
		1st Year Plant Height (m)		
Total	31	2.709788		
Linear component	**1**	**0.057760**	**0.65**	**.4253**
Deviations from linear	30	2.652028		
Quadratic component	**1**	**0.003613**	**0.04**	**.8437**
Deviations from quadratic	29	2.648415		
Cubic component	**1**	**0.007840**	**0.08**	**.7752**
Deviations from cubic	28	2.640574		
		2nd Year Plant Height (m)		
Total	31	7.013750		
Linear component	**1**	**0.060062**	**0.26**	**.6144**
Deviations from linear	30	6.953688		
Quadratic component	**1**	**0.101250**	**0.43**	**.5179**
Deviations from quadratic	29	6.852438		
Cubic component	**1**	**0.115563**	**0.48**	**.4940**
Deviations from cubic	28	6.736875		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability = 15.8% and 16.9% for 1st and 2nd year, respectively (estimated with error term of cubic model).

Experimental mean = 1.946 m and 2.907 m for 1st and 2nd year, respectively.

Table 44. Regression analysis of the relationship between fertilizer rate and 1st and 2nd year plant height for *Taxodium distichum*, *Expt. 4.*

Source	df	Sums of squares	F value	$Pr > F^z$
		1st Year Plant Height (m)		
Total	31	1.329022		
Linear component	**1**	**0.023281**	**0.53**	**.4702**
Deviations from linear	30	1.305741		
Quadratic component	**1**	**0.052003**	**1.20**	**.2818**
Deviations from quadratic	29	1.253738		
Cubic component^y	**1**	**0.247276**	**6.88**	**.0140***
Deviations from cubic	28	1.006462		
		2nd Year Plant Height (m)		
Total	31	2.799997		
Linear component	**1**	**0.003706**	**0.04**	**.8433**
Deviations from linear	30	2.796291		
Quadratic component	**1**	**0.097903**	**1.05**	**.3135**
Deviations from quadratic	29	2.698388		
Cubic component^x	**1**	**0.431601**	**5.33**	**.0285***
Deviations from cubic	28	2.266787		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

[y]The cubic regression equation is $y = 3.3925 - .023365575x + .000133574\,x^2 - .000000221\,x^3$, $r^2 = .24$.

[x]The cubic regression equation is $y = 4.7225 - .031011905x + .00017618\,x^2 - .000000292\,x^3$, $r^2 = .19$.

Coefficient of variability = 8.3% and 8.9% for 1st and 2nd year, respectively (estimated with error term of cubic model).

Experimental mean = 2.278 m and 3.205 m for 1st and 2nd year, respectively.

Table 45. Regression analysis of the relationship between fertilizer rate (kg N/ha) and 1st and 2nd year trunk caliper for *Acer rubrum*, *Expt. 4.*

Source	df	Sums of squares	F value	Pr > F[z]
		1st Year Trunk Caliper (cm)		
Total	31	6.03029		
Linear component	**1**	**0.19182**	**0.99**	**.3287**
Deviations from linear	30	5.83847		
Quadratic component	**1**	**0.00320**	**0.02**	**.9005**
Deviations from quadratic	29	5.83527		
Cubic component	**1**	**0.73984**	**4.07**	**.0535**
Deviations from cubic	28	5.09543		
		2nd Year Trunk Caliper (cm)		
Total	31	17.99355		
Linear component	**1**	**1.20409**	**2.15**	**.1528**
Deviations from linear	30	16.78946		
Quadratic component	**1**	**1.43651**	**2.71**	**.1103**
Deviations from quadratic	29	15.35295		
Cubic component	**1**	**0.18632**	**0.34**	**.5622**
Deviations from cubic	28	15.16663		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability = 14.4% and 18.3% for 1st and 2nd year, respectively (estimated with error term of cubic model).

Experimental mean = 2.97 cm and 4.03 cm for 1st and 2nd year, respectively.

Table 46. Regression analysis of the relationship between fertilizer rate (kg N/ha) and 1st and 2nd year trunk caliper for *Betula nigra, Expt. 4.*

Source	df	Sums of squares	F value	Pr > F[z]
		1st Year Trunk Caliper (cm)		
Total	31	3.81962		
Linear component	**1**	**0.07140**	**0.57**	**.4556**
Deviations from linear	30	3.74822		
Quadratic component	**1**	**0.37123**	**3.19**	**.0846**
Deviations from quadratic	29	3.37699		
Cubic component	**1**	**0.03580**	**0.30**	**.5882**
Deviations from cubic	28	3.34119		
		2nd Year Trunk Caliper (cm)		
Total	31	10.34240		
Linear component	**1**	**0.00028**	**0.00**	**.9776**
Deviations from linear	30	10.34212		
Quadratic component	**1**	**0.29325**	**0.85**	**.3652**
Deviations from quadratic	29	10.04887		
Cubic component	**1**	**0.00198**	**0.01**	**.9413**
Deviations from cubic	28	10.04689		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability = 13.0% and 16.1% for 1st and 2nd year, respectively (estimated with error term of cubic model).

Experimental mean = 2.66 cm and 3.73 cm for 1st and 2nd year, respectively.

Table 47. Regression analysis of the relationship between fertilizer (kg N/ha) rate and 1st and 2nd year trunk caliper for *Liriodendron tulipfera*, *Expt. 4.*

Source	df	Sums of squares	F value	Pr > F[z]
		1st Year Trunk Caliper (cm)		
Total	23	13.26830		
Linear component[y]	**1**	**4.11899**	**9.90**	**.0047****
Deviations from linear	22	9.14921		
Quadratic component	**1**	**0.10926**	**0.25**	**.6196**
Deviations from quadratic	21	9.04005		
Cubic component	**1**	**0.02919**	**0.06**	**.8017**
Deviations from cubic	20	9.01086		
		2nd Year Trunk Caliper (cm)		
Total	23	37.97036		
Linear component[x]	**1**	**9.83360**	**7.69**	**.0111***
Deviations from linear	22	28.13676		
Quadratic component	**1**	**0.75280**	**0.58**	**.4558**
Deviations from quadratic	21	27.38396		
Cubic component	**1**	**0.22854**	**0.17**	**.6860**
Deviations from cubic	20	27.15542		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

[y]The linear regression equation is $y = 3.86951 - .004868866x$, $r^2 = .31$.

[x]The linear regression equation is $y = 5.97660 - .007522964x$, $r^2 = .26$.

Coefficient of variability = 22.4% and 25.2% for 1st and 2nd year, respectively (estimated with error term of cubic model)

Experimental mean = 3.00 cm and 4.63 cm for 1st and 2nd year, respectively.

Table 48. Regression analysis of the relationship between fertilizer rate (kg N/ha) and 1st and 2nd year trunk caliper for *Pinus Elliotti*, *Expt. 4.*

Source	df	Sums of squares	F value	Pr > F[z]
		1st Year Trunk Caliper (cm)		
Total	31	30.80719		
Linear component	**1**	**1.26202**	**1.28**	**.2666**
Deviations from linear	30	29.54517		
Quadratic component	**1**	**0.42090**	**0.42**	**.5225**
Deviations from quadratic	29	29.12427		
Cubic component	**1**	**1.30141**	**1.31**	**.2621**
Deviations from cubic	28	27.82286		
		2nd Year Trunk Caliper (cm)		
Total	31	41.53697		
Linear component	**1**	**0.88953**	**0.66**	**.4242**
Deviations from linear	30	40.64744		
Quadratic component	**1**	**2.79070**	**2.14**	**.1545**
Deviations from quadratic	29	37.85674		
Cubic component	**1**	**1.80413**	**1.40**	**.2465**
Deviations from cubic	28	36.05261		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability = 20.0% and 17.7% for 1st and 2nd year, respectively (estimated with error term of cubic model)

Experimental mean = 4.97 cm and 6.42 cm for 1st and 2nd year, respectively.

Table 49. Regression analysis of the relationship between fertilizer rate (kg N/ha) and 1st and 2nd year trunk caliper for *Quercus virginiana, Expt. 4.*

Source	df	Sums of squares	F value	Pr > F[z]
		1st Year Trunk Caliper (cm)		
Total	31	6.06340		
Linear component	**1**	**0.61504**	**3.39**	**.0756**
Deviations from linear	30	5.44836		
Quadratic component	**1**	**0.14580**	**0.80**	**.3792**
Deviations from quadratic	29	5.30256		
Cubic component	**1**	**0.02401**	**0.13**	**.7239**
Deviations from cubic	28	5.27855		
		2nd Year Trunk Caliper (cm)		
Total	31	12.70692		
Linear component[y]	**1**	**1.57807**	**4.25**	**.0479***
Deviations from linear	30	11.12885		
Quadratic component	**1**	**0.01853**	**0.05**	**.8275**
Deviations from quadratic	29	11.11032		
Cubic component	**1**	**0.02328**	**0.06**	**.8102**
Deviations from cubic	28	11.08704		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

[y]The linear regression equation is $y = 4.563125 - .002364583x$, $r^2 = .12$.

Coefficient of variability = 16.2% and 15.5% for 1st and 2nd year, respectively (estimated with error term of cubic model)

Experimental mean = 2.69 cm and 4.07 cm for 1st and 2nd year, respectively.

Table 50. Regression analysis of the relationship between fertilizer rate (kg N/ha) and 1st and 2nd year trunk caliper for *Taxodium distichum, Expt. 4.*

Source	df	Sums of squares	F value	Pr > F[z]
		1st Year Trunk Caliper (cm)		
Total	31	10.51220		
Linear component	**1**	**0.22500**	**0.66**	**.4243**
Deviations from linear	30	10.28720		
Quadratic component	**1**	**0.02645**	**0.07**	**.7865**
Deviations from quadratic	29	10.26075		
Cubic component	**1**	**1.33225**	**4.18**	**.0505**
Deviations from cubic	28	8.92850		
		2nd Year Trunk Caliper (cm)		
Total	31	77.70775		
Linear component	**1**	**3.84400**	**1.56**	**.2211**
Deviations from linear	30	78.86375		
Quadratic component	**1**	**5.42851**	**2.30**	**.1402**
Deviations from quadratic	29	68.43524		
Cubic component	**1**	**2.37656**	**1.01**	**.3241**
Deviations from cubic	28	66.05868		

[z]Probability (Pr) of a greater F value. Significance is denoted as significant at 5%(*) or 1%(**) levels.

Coefficient of variability = 10.0% and 20.3% for 1st and 2nd year, respectively (estimated with error term of cubic model).

Experimental mean = 5.68 cm and 7.56 cm for 1st and 2nd year, respectively.

VITA

Donald Lee Fuller, the son of Donald E. and Marion M. Fuller, was born in Erie, PA, on October 12, 1955.

He graduated from McDowell High School at Erie, PA, in May, 1973. He entered Pennsylvania State University in September, 1973, and was graduated from there in May, 1977, with a Bachelor of Science degree in Plant Science. In June, 1979, he enrolled in the Graduate School at Louisiana State University and received his Master of Science degree in Horticulture in December, 1982.

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DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Donald L. Fuller

Major Field: Horticulture

Title of Dissertation: Root and Top Growth Response of Five Woody Ornamental Species to In-field Fabric Containers, Bed Height, Trickle Irrigation, Fertilizer Source and Fertilizer Rate in Louisiana

Approved:

Warren A. Meadows

Major Professor and Chairman
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July 13, 1988